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American Mathematical Society, 501 West 116th St., New York, N. Y.

Società degli Spettroscopisti Italiani, Catania, Italy.

Sociedad Cientifica "Antonio Alzate," Mexico, Mexico.

Solar Observatory, Mount Wilson, via Pasadena, Cal.

American Philosophical Society, 105 South Fifth St., Philadelphia, Pa.

Harvard College Observatory, Cambridge, Massachusetts.

The Monthly Evening Star Map, 150 Nassau St., New York, N. Y.

The Astronomical Herald, Tokyo, Japan.

Publications of Pomona College, Claremont, Cal.

The Astronomical Journal, Albany, N. Y.

Journal de Physique, 5 Rue de la Santé (13^{e}), Paris, France.

Journal of the Royal Astronomical Society of Canada, 198 College Street, Toronto, Canada.

Ciel et Terre, 24 Avenue des Villas, Bruxelles, Belgium.

ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO PROFESSOR J. C. KAPTEYN.

By Heber D. Curtis.

Americans are firm believers in all that is implied in the expression, "the man behind the gun," and none of us are inclined to deny that the man is, in general, more important than his equipment. But, while always ready to admit the truth of this familiar phrase, it must be said that we, as a people, are very prone to be dazzled by mere bigness; we are too apt to feel that our universities are necessarily great merely because of the great numbers of students which many of them have; that our laboratories are necessarily world-famed because of the magnificence of their equipments. Holland is not a large country. It possesses four universities; we have in America at least half a dozen universities, each of which has more students, and perhaps more buildings and equipment, than all four of Holland's universities taken together. But a casual survey of the faculty lists of these four Dutch universities shows a striking number of world-famous names in certain fields of science; it is doubtful if we could pick out in four great American universities an equal number of men who could take rank with such names as Lorentz, Kammerlingh-Onnes, De Vries, Van der Waals, or Zeeman.

The popular idea of an astronomer is that of a man whose work is entirely at night time, with a telescope; the larger the telescope, the greater the astronomer; a point of view which is very far from representing the whole truth. Observations, by themselves, unless properly studied and subjected to calculation, are not of very great value, and in most lines of astronomical work sufficient observations can be secured in one night to keep the observer busy for a week at his desk. Naturally, without the observations which form its foundation, there could properly be no astronomical science as we know it, but there is also the need for keen minds to piece together and arrange in order the facts collected by observation from the millions of separate units which form our universe, to study the greater equations of our cosmos. The Bruce Medal, which is bestowed by the Astronomical Society of the Pacific for distinguished services to astronomy, has now been awarded to ten famous astronomers, and it is worthy of note that four of the ten might properly be termed astronomers without a telescope, men who, at the time of their greatest work, seldom or never looked through a telescope. One of these, a world-famous mathematical astronomer, once said jokingly that he was rather doubtful whether he would be able to pick out the correct end of a telescope to look through.

The University of Groningen, Holland, is the smallest of the four Dutch universities; its students number about five hundred. In a few rooms of a building in this city is located the Astronomical Laboratory of Groningen, a department whose annual stipend from the university in 1906 was only about $1,000 a year. It is in truth an observatory without a telescope; its only instruments are three microscopes for measuring photographic star plates. Modest as is the equipment, the Publications of the Astronomical Laboratory at Groningen are well and favorably known to astronomers the world over. Professor J. C. KAPTEYN is the director of this Astronomical Laboratory, and in connection with the bestowal of the Bruce Medal of the Astronomical Society of the Pacific upon Professor KAPTEYN, it will be of interest to review briefly some points of the work which has been accomplished by this astronomer, with very modest equipment and resources.

It has been said that the perfectly pure note of a fine violin or the voice of a great singer can always be easily heard above the complex of sounds given by the greatest accompanying orchestra, and, similarly, a life devoted solely and purely to one ideal is pretty certain to make itself felt. I can give you to-night no better idea of the devotion to astronomical science which has always characterized our medalist than to quote some passages of the correspondence which passed between Professor KAPTEYN and Sir DAVID GILL in connection with the great Photographic Durchmusterung of the Observatory of the Cape of Good Hope.

This was nearly thirty years ago, and the possibilities of the

THE ASTRONOMICAL LABORATORY AT GRONINGEN.

photographic plate as a means of mapping of the stars of the sky were just being realized. Sir David Gill was anxious to apply this new photographic method to the charting of the stars of the southern heavens; while the Cape Observatory had sufficient funds to provide for taking the photographic plates which should cover the entire sky from declination — 19° to the South Pole, there was no money available to provide for the tremendous task of measuring and reducing the star images on these plates. The final catalogue contains more than 450,000 stars.

It was at this juncture that Professor Kapteyn offered his help. I will here quote some extracts from his letter to Sir David Gill:—

> I have still to explain to you the proposal in my former letter, which I thought it better not to postpone—my resolution being taken. In doing this you will excuse me for premising so much about my private circumstances as seems necessary for the purpose.
>
> In the year 1878 I was appointed Professor of Astronomy and Theoretical Mechanics at the University of Groningen, having been before, during a couple of years, observer at the Leiden Observatory. Directly on my appointment I proposed to the government to fit out a little observatory . . . Perhaps I shall succeed after some years in getting one or two instruments with which truly scientific work may be prosecuted; but at all events a very long time will have to elapse before any such result may be looked for. The first years of my professorship once passed, my lectures left me considerable leisure, which it has always been my desire to devote to astronomical observations. . . . Now, after your success in stellar photography, and especially after your letter in which you tell me, "I am obliged to crave help where I can get it," it has occurred to me that by measuring and reducing your photographs I could contribute very effectually toward the success of an enormous and eminently useful undertaking. Since then I have revolved the idea in my mind and I have come to the conclusion that if you will let me, and if I can secure the necessary help, there is no one in better condition to undertake this work than myself. . . .
>
> I have kept this letter here some days to talk the matter of the Photographic Durchmusterung over with Professor Bakhuyzen and his brother. I am bound to say that they were not very enthusiastic over the matter; of course, they thought the results, once reached, of immense value, but the drudgery to be gone through before these results are once got into the form of a catalogue is almost unbearable. However, I think my enthusiasm for the matter will be equal to (say) six or seven years of such work. . . .

The three great volumes of the Cape Photographic Durchmusterung to-day form a worthy memorial to Professor KAPTEYN's single-hearted devotion to his chosen life work. An astronomer without instruments, he did not let this lack keep him from the attempt to do valuable work wherever he could find it to do. It was not a class of work affording the same vivid interest to the investigator as that which is given by many other lines of research; it was in no sense popular, in the common acceptance of that term, but hard, monotonous routine. The completed work took over twelve years instead of the six or seven which KAPTEYN had anticipated; the two rooms in which the work was carried on were loaned to Professor KAPTEYN by a fellow professor at Groningen, so that the Cape Photographic Durchmusterung, strange as it may sound, as far as the catalogue is concerned, may be said to have emanated from the Physiological Laboratory at Groningen.

Like every other science and every other occupation, the science of astronomy is to-day highly specialized. It has been stated that the death of the great mathematician SYLVESTER marked the passing of the last man who could be said to be truly an authority in every branch of the mathematics of his day, and no mathematician to-day pretends to be thoroughly conversant with more than one or two fields of this vast and complex science. The case in astronomy is much the same. The modern astronomer, frequently an entire observatory, to-day devotes energy to one rather narrowly limited field, and attempts few observations on other fields. To illustrate: At the start the Lick Observatory took daily photographs of the Sun, but discontinued this about ten years ago, and the photoheliograph has since been dismounted, solely for the reason that the same work was being done at other observatories with equal or more powerful equipments, and it seemed wiser to expend our efforts on lines of work which could be better done here than elsewhere, and to avoid useless duplication.

There is, however, one greater aspect of the subject as a whole toward which all astronomers are more or less indirectly working, an astronomy into which some day all the results from the lesser divisions of this science will finally fit, each fragment of knowledge gained by minute specialization tending to form a harmonious whole, a perfect pattern. In this greater field are combined our studies as to the nature and size of our stellar universe, its past, and future history.

How large is this universe of stars in which our Sun forms so inconspicuous a unit? Is it finite or infinite? Is there some plan underlying the whole, or is the arrangement of these millions of separate units merely a haphazard one? How has our universe attained its present form, and what can we say of its probable future history? All these form a part of the greater questions which astronomy is trying to answer, and toward the correct answer to these questions are directed all the minute researches on this or that star, the observations made with hundreds of telescopes, the mathematical researches, the dry bones of statistics, which, to the lay mind, seem so far removed from the interesting observations and speculations which make astronomy so popular a subject. Astronomy has not yet answered all these greater questions, and perhaps may never be able to answer them fully.

It is in the study of some of these greater problems of our stellar universe that Professor KAPTEYN has done much of his most valuable work. His observatory has been his desk and a room fitted with instruments for measuring photographic plates; his subject-matter photographic plates and observations of star positions made by other astronomers; his tools the methods of mathematical analysis.

A great deal of our medallist's most valuable work has been in the field of stellar motions; it is not easy to give many of the details of these researches or to indicate the full measure of their difficulty without introducing technicalities of little interest to the general reader. However, a few simple comparisons may perhaps be of service in indicating the minuteness of the data which form the subject-matter of such researches, investigations to which each advance in our astronomical knowledge seems to add new complexities. The workings of the law of gravitation, as exemplified in our solar system, are now so well known that it is not a very difficult task for the astronomer to tell quite accurately in what part of the sky a given planet was at a certain date one thousand years ago, or where it will be one thousand years from now. But there is no such apparent regularity in the phenomena of our stellar universe. The small proper motions of the stars appear at first sight to be entirely at random. We know from the spectrograph that the radial motions may average five to ten miles in every second of time, but the distances are so inconceivably great that actual movements amounting to billions of miles will, in general, change their apparent positions in the sky by amounts almost too small to measure. To illustrate: If we, in San Francisco, were able with our telescopes to see a man in Los Angeles, and that man were to move a distance of ten feet in one year's time, it would appear to us that this motion was inconceivably slow, and impossible of detection. This would, however, be a very large "proper motion" as compared with the actual movements of the stars; in fact, there are only about one hundred stars known which would move, in one year, over a space in the sky which would look as large as ten feet would in the distance from San Francisco to Los Angeles. For the average naked-eye star the motion across our line of vision would correspond more nearly to about six inches a year when seen at this distance. Impossible to measure with any telescope, you may say. This is true, if we were to try to measure only the six inches moved by our hypothetical Los Angeleno in one year, but in one hundred years the accumulated effect would amount to fifty feet, still a very small quantity, but possible to detect. So with the minute proper motions of the stars; imperceptible in most cases in a year's time, these motions come within the reach of our measuring instruments when sufficient time has elapsed. So it turns out, that for the solution of some of the questions as to the size of our universe and the motions of the stars which form it, carefully made old observations of a star's position become very valuable. The patient astronomers, who, for one hundred and fifty years past, have carefully observed the accurate positions of the stars, builded better than they knew; their observations will never entirely lose their value, though few of these observers doubtless dreamed of the precise way in which their dry routine of observation would help in solving the problems of a hundred years in the future. These minute proper motions will, after a great lapse of time, completely change the aspect of certain constellations as we know them

Five stars of the familiar Big Dipper are moving in one direction in common, while the other two are moving toward a different part of the sky; so it is that an observer two hundred thousand years ago, or one two hundred thousand years from now, would look in vain for this familiar configuration of stars as we see it to-day.

The problem of finding the laws governing these apparently haphazard and very minute motions is a very complicated one; it is much as though we had set before us the problem of determining the law governing the arrangement and movements of a large swarm of gnats or fireflies.

At present we know with considerable accuracy the minute proper motions across our line of vision for several thousand stars, and one of the greater questions which astronomy must answer in its attempt to portray the size and structure of this universe of stars is whether any law governs these apparently random movements. This is the field in which Professor Kapteyn has made some of his most striking discoveries. I have tried to indicate, in a general way, how complicated and difficult this question is; a further cause of complexity is introduced by the fact that our Sun and its system is, like other stars, not at rest, but moving toward a point in *Hercules* at a rate of about twelve miles in every second of time, and the effect of this motion must be removed from the observed proper motions of the stars. With so many small motions of varying directions and amounts, the problem becomes largely one of averages, and the methods statistical. The stars must be sorted out by magnitudes and spectral classes, then again by the size and general direction of their proper motions, taking into account our rather meager knowledge of stellar distances. By such statistical methods of sorting and arranging the stars in terms of their motions, positions, brightness, and age as shown by their type of spectrum, Professor Kapteyn has made a number of striking contributions to modern astronomy; perhaps the best known of these is his discovery that the brighter stars show a well-defined tendency to move toward two diametrically opposed points in the sky, rather than entirely at random. These two points of preferential motion are in the Milky Way; one of them being about seven degrees northeast of the bright star

Betelgeuze in *Orion*, and the other one at the antipodal point on the other side of the celestial sphere, north of the constellation of *Sagittarius*. Many other investigators have since studied this problem, and the evidence of the spectrographic results in general supports this two-drift theory, but do not indicate it so strongly as do the proper motions. There is also a well-marked tendency for many of the stars to move in planes roughly parallel to that of the Milky Way, but recent results tend to show that stars of different ages behave differently in this regard.

Professor KAPTEYN's results on star-streaming were secured, as I have said, by what we may term statistical methods applied to the very minute proper motions of the stars. There is one fault in such methods, which lies in the fact that the apparent motion of a star in space tells us nothing as to the distance of the star or its actual motion in miles per second, unless we have knowledge as to the distance of the star from other sources. A simple illustration may make this point clear; a motion of one second of arc per year across our line of vision would be equivalent, if we were looking, for example, at the branch of a tree one hundred feet away, to a motion or growth of only one two-hundredth of an inch per year; at the distance of the Sun it would equal four hundred and fifty miles per year; while for a star one hundred light years away, it would mean a motion of nearly three billion miles per year, or ninety miles a second. Now, the spectrograph enables us to tell in miles per second how fast a star is moving directly toward or directly away from us, no matter what the distance of the star may be. So it is that a combination of our knowledge of the proper motions of the stars with the values of the actual radial velocities in miles per second secured by the spectrograph has in recent years given us more accurate values of the real motions and average distances of the stars. For this reason some of Professor KAPTEYN's conclusions, particularly with regard to the size of our stellar universe, have been somewhat modified in recent years, but this fact in no way detracts from the value of the methods which he has applied and where he has in many cases pointed the way to future advances when our knowledge of radial velocities shall be relatively as complete as in the case of stellar proper motions.

Other valuable pieces of work carried through by our medalist are his extensive researches on the proper motions of the stars by means of photography, and also his researches on stellar parallax by the same method.

It was KAPTEYN, too, who perhaps first fully realized the difficulties which bar our way to future progress in the knowledge of these greater problems of stellar distribution, type, distance, and motion, for this knowledge seems absolutely beyond our finite resources should we attempt to find out everything about every star. With a total number of stars generally estimated at about two hundred million, should these be investigated individually it would be centuries before all the observatories of the world could begin to find out all we wish to know in our efforts to fathom the plan or plans underlying our universe of stars. We ought to know a great number of proper motions, and we now know such motions accurately for only a few thousand stars; we ought to know their stellar age as given by the type of spectrum which they show, and this we know for fewer than ten thousand stars at present, though the work at Harvard will bring this number up to about 140,000 in the near future; we ought to know their actual speed in miles per second, and the spectrograph has thus far given us fewer than two thousand radial velocities; we ought to know the distances of many of them, and thus far we know the individual distances of fewer than two hundred stars with any accuracy, and these distances are for our nearest stellar neighbors. All these gaps in our knowledge make it seem like a task too great for mankind ever to gain more than a superficial knowledge of the real nature and structure of this universe of stars. But now suppose that instead of trying to find out these facts for most of the stars of the sky, we select quite a number of relatively small sections of the sky distributed very uniformly over the heavens, and suppose further that the main observatories of the world so combine their efforts as to find out for all these small representative squares everything that can be found out with reference to the proper motions, radial velocities, spectral types, and distances of the stars in each square. From a general average of the fairly complete knowledge which would thus be secured for these representative sections of the sky we should then have data which would enable us to learn the laws of this stellar universe almost as accurately as though we had attempted the impossible task of studying, if not every star, at least a very large proportion of the stars. This plan of systematizing the ascertainable facts of our stellar universe by co-operative studies on numerous small representative sections of it is due to our medallist, and is known as KAPTEYN'S Plan of Selected Areas; already a number of observatories are concentrating their efforts on these areas. Some such subdivision of the task and concentration of effort on relatively small representative areas seems to offer us the only means of solving the problems of an infinite universe with only finite time and finite resources at our disposal.

Let us now attempt to give briefly a conspectus of the more salient features of this universe of stars; many points are still uncertain, and the astronomer prefers to state many of his conclusions as only probably true, in view of the fact that for many of his deductions the data thus far gathered forms only a beginning.

The first point which should be emphasized is the essential oneness of the stellar universe in its subject-matter. In the spectrum of the Sun we find great numbers of absorption lines which we know stand for certain chemical elements, iron, calcium, hydrogen, etc., and to the best of our knowledge the light given forth by burning iron, for example, will show the same lines in our laboratories here on Earth as it will in the far greater laboratory of a star at the limit of our visible universe. It is probable that all the elements we know are present in the Sun, though not all have been identified as yet. There are only about eighty-three elements or kinds of matter known to us; just why there should thus be so small a number of arrangements of atoms instead of an infinite number of kinds of matter, the chemist and physicist can not yet explain. Similarly, we find stars, and many of them, distant billions of billions of miles from us, which show essentially the same spectrum as our Sun. A still larger number of stars show the lines of fewer elements, mainly hydrogen, magnesium, calcium and helium, and there are still left lines which we cannot yet identify with known terrestrial elements, but such unknown lines are relative few, and we expect eventually to be able to identify even these. For a long time, to illustrate, certain lines were observed in the spectrum of the Sun and many stars which had no counterpart on the Earth; the unknown element was called helium. Years later physicists discovered small amounts of this gaseous element on the Earth. The nebulæ offer many puzzles not yet explained, and it may be, as a few astronomers have argued, that we here see matter beginning to be, in forms and conditions yet unknown to us, but for the stars we may say that, for distances out into space so inconceivable that light needs thousands of years to make the journey, the stars show a oneness with the materials which make up our own Sun and Earth; like our Earth, the stars evidently are formed of only a finite number of kinds of matter. Though we to-day accept this fact as almost self-evident, this oneness of the matter in the tremendous reaches of space is an inspiring fact and full of meaning.

Secondly, we discern everywhere in this universe of stars the evidences of a process of evolution, a cycle, perhaps recurrent, of growth and decay. From the formless nebula and the great expanses of diffused nebulosity, through the spirals, to the clusters and such stars as the Pleiades with the remnants of their original nebulosity still surrounding them, the evidence of an evolutionary process seems clear, though we know little as to the actual laws governing the growth. Of the brighter stars, at least one in every four is a double star; whether this proportion continues among the fainter stars we have no means of knowing, but there is certainly a strongly marked tendency for the fission of the parent mass into two suns of nearly equal size.

Thirdly, these millions of suns are moving in all directions at speeds of from five to ten or more miles in a second. There are great groups of suns whose separate units are light-years apart which are traveling together through space; such groups, for instance, as the great *Taurus* group discovered by Boss, or those aggregations which Kapteyn found with motions tending toward his vertices of preferential motion. Here, perhaps, the most striking fact is that the speed appears to be a function of the star's spectral type; the older the star, the higher its speed in space. As pointed out by CAMPBELL and KAPTEYN, it is as though matter in the ante-stellar state were in some way not subject to the attraction of gravitation.

Finally, when we attempt to visualize the dimensions of this universe of stars, we must confess that our knowledge is most fragmentary and imperfect; at present we know the distances of only those stars which form the inner fringe of the stellar universe in which our Sun is but a very inconspicuous unit. Our present direct methods enable us to determine the distances of stars with some confidence out to about one hundred and fifty light-years, nearly a quadrillion miles, but beyond this distance but little confidence can be felt in direct determinations of stellar distances. By combining the results of proper motions and radial velocity data it is possible to find the average distances of large groups of stars. The brighter stars of solar type have an average distance from us of about one hundred light-years (the ten nearest stellar neighbors of the Sun would be contained in a sphere twenty-five light-years in diameter), while the younger Class B stars are on the average about five hundred light-years from our system. Eventually this method will enable us to determine distances still farther out in space, perhaps to one or two thousand light-years, but here there appears to be a wall which may bar all further progress by known methods. This is because for the fainter and more remote stars it becomes increasingly more difficult to photograph them with the spectrograph, and the proper motions are doubtless so minute that several centuries of observation instead of one century may be necessary. Beyond the confines of a sphere about one thousand light-years in diameter, then, we really know nothing to-day; our estimates of the probable size of the visible universe are all but little more than guesses, all rest on more or less probable assumptions. We can be guided only by the analogy of our own Sun, which at the distance of the average naked-eye star would be visible only in a telescope, and by what little we already know of star distances, with more or less probable hypotheses as to the existence and amount of an absorption of light in space. So it is that for the probable diameter of the belt of stars which forms the Milky Way the estimates vary all the way from three thousand to at least a million light-years.

Such researches apparently do not touch, even remotely, the daily life of this practical age. But if to know, or even to know that one knows, is power, a knowledge of these greater facts of our universe is certainly an asset of great, though indirect, value to our social fabric. The Sun is not swallowed up by a great dragon at the time of an eclipse; the aurora is not a procession of departed spirits trooping across the sky; the Sun and the stars do not revolve in their crystal spheres about an Earth which is the center of all. To realize, even in part, the majesty of this universe of stars is a possession of value to the soul of any man.

PRELIMINARY NOTE ON AN ATTEMPT TO DETECT THE MAGNETIC FIELD OF THE SUN.

By George E. Hale

In 1908, shortly after magnetic fields had been found in sunspots, an attempt was made to observe the Zeeman effect due to the general magnetic field of the Sun with the 60-foot tower telescope and 30-foot spectrograph of the Mount Wilson Solar Observatory. Although slight shifts of certain solar lines, such as might be caused by a magnetic field, were found on measuring the photographs, the quantities were too small to command confidence, and the work was postponed until more perfect polarizing apparatus could be provided.

The investigation was resumed in October, 1911, but no certain evidences of the Zeeman effect were detected. On the completion of the 150-foot tower telescope and 75-foot spectrograph, observations were begun with this instrument in January of the present year (1912). The objective of 150 feet focal length now used with this telescope was not then ready, and accordingly the 12-inch objective of 60 feet focal length, belonging to the 60-foot tower telescope, was temporarily transferred to the new tower. This forms an image of the Sun 6.7 inches in diameter on the slit of the spectrograph. After passing through the slit the light descends vertically into a well, excavated in the earth beneath the tower, to a depth of 75 feet. where it falls upon the objective which serves for both collimator and camera of the auto-collimating spectrograph. We were fortunate in having a large grating of the finest quality, ruled by Michelson, which gives almost theoretical resolution in the third order spectrum. Here the scale is 4.9^{mm} to the Ångström unit, corresponding to a distance of 29^{mm} between the D lines.

Let us assume the Sun's magnetic field to be similar to that of a magnetized sphere, with magnetic poles coinciding in position with the poles of rotation. If the field were strong enough, and if the observer could look along the Sun's axis, and form an image of one of the magnetic poles on the slit of a power-his spectrograph, he would find certain solar lines split into doublets, with components circularly polarized in opposite directions. If a Nicol prism were placed in front of the slit of the spectrograph, with its long axis parallel to the slit, in combination with a quarter-wave plate set with its principal section at an angle of 45°, one of the components of the magnetic doublets would be extinguished, while the other would be transmitted by the Nicol. If we assume the red component to be transmitted, rotation of the quarter-wave plate through an angle of 90° would cause this to be extinguished and the violet component to be transmitted. Consequently, if the quarter-wave plate were built up of mica strips 2^{mm} wide, mounted so that the principal sections of successive strips make an angle of 45° with the slit and 90° with each other, the Nicol would transmit (say) the red component for the odd strips and the violet component for the even strips. In a photograph of the spectrum the lines would have a zigzag appearance, the magnitude of the separation of the components shown on successive strips varying directly with the strength of the field. If the slit of the spectrograph were directed, not at the Sun's pole, but at a point in 45° latitude, the effect would still be clearly observable, though the transformation of the circularly polarized light of the components into elliptically polarized light would result in less complete extinction by the Nicol.

In practice, on account of the weakness of the Sun's magnetic field, in comparison to the fields of sun-spots, complete separation into doublets is not to be expected. The superposition of the components would result in a slightly widened line, with edges elliptically polarized in opposite directions. It was hoped that a spectrograph of very high dispersion might reveal slight shifts of the lines, caused by the extinction of the red and violet edges by the successive strips of the quarter-wave plate. The increasing ellipticity of the light, in passing from high to low latitudes, would involve less and less complete extinction. This, coupled with the decrease in the total magnetic intensity toward the equator, would be indicated by decreasing displacements of the line. The sign of the displacements should be reversed in passing from the northern to the southern hemisphere.

With the aid of the polarizing apparatus described above, a series of photographs of the region near the D lines in the third order spectrum was made with the slit at various latitudes on the central meridian of the Sun. The photographs were measured by Miss Lasby, who had acquired much experience in the measurement of extremely small displacements of solar lines. The measures were made without possible bias, as the latitude corresponding to the plate was not known to the observer. With very few exceptions, the displacements were found to be positive in the northern hemisphere and negative in the southern hemisphere of the Sun, the magnitude of the displacements decreasing from a maximum near 50° north or south latitude, to zero near the equator.

The conditions were extremely favorable for the detection of very small shifts of the solar lines, as the spectrograph is very massive and stable, the grating is mounted in a region of practically constant temperature about 75 feet below the level of the ground, and the method of observation is a purely differential one, the displacements measured being those of sections of the same line corresponding to adjoining strips of the quarter-wave plate. As a check upon the results, atmospheric lines were measured and found to give shifts rarely exceeding 0.0002 Ångström, while some of the solar lines gave shifts as great as 0.003 Ångström. Nevertheless, there were certain peculiarities about the results which made it advisable to take every possible precaution to check their reliability.

The most marked of these peculiarities lay in the fact that only a few of the solar lines seemed to be affected, others showing no shifts, although they were known to give large Zeeman effects in the laboratory. In our work on the spectra of sunspots, it is true, we had found that the magnetic field is very strong at low levels, but decreases rapidly in passing upward through the spot vapors. If some analogous condition exists in the case of the general field, certain low-level lines may show it, while those corresponding to higher levels may fail to do so.

As a check on the question whether the displacements of the solar lines might safely be attributed to a magnetic field, a half-wave plate was inserted between the compound quarter-wave plate and the Nicol. Leaving the quarter-wave plate and

Nicol untouched, it should be possible to reverse the sign of the displacement in any given case by turning the half-wave plate through an angle of 45°. A number of tests were made in this way, and in all cases Miss LASBY's measures showed shifts such as would occur if the edges of the lines were circularly or elliptically polarized. A similar test was applied by omitting the half-wave plate, and inverting the compound quarter-wave plate, so as to bring its lower face uppermost. This also reversed the sign of the displacement, and proved so satisfactory a means of checking the observations that the plan of taking all plates in pairs, corresponding to the two positions of the quarter-wave plate, was subsequently adopted.

Up to this time all of the measures had been made by Miss LASBY, except for a few check measures by Mr. ADAMS. As it seemed desirable to have a complete series of independent measures of the plates, several members of the observatory staff undertook the work. It was found, however, that while in many cases the measures showed excellent internal agreement, there was no general harmony among the observers. It was evident that with the lines in question systematic errors were likely to occur, frequently of such a magnitude as to reverse the sign of the measured displacement. Two attempts to avoid this difficulty were accordingly made. A parallel plate micrometer, in which the line corresponding to one of the strips of the compound mica plate is displaced to right or left by inclining a plate of plane parallel glass, mounted immediately above the negative, was substituted for the ordinary measuring machine used in the previous work. With this simple device, the use of which for this purpose was suggested by Mr. PEASE, the line is shifted until it coincides with the line of an adjoining strip of the spectrum, and the magnitude of the displacement is read off on a graduated arc, which measures the angle through which the plate is turned.

All of the plates of the first series have been measured with this instrument by Dr. VAN MAANEN, with results agreeing well with those of Miss LASBY, except that there seems to be a systematic tendency toward smaller values for the displacements on the part of Dr. VAN MAANEN. Thus, while the true magnitude of the displacement for a given latitude is still open to further investigation, there is no question as to the reversal of the sign of the displacements in the two hemispheres, and the decrease in their magnitude from middle latitudes toward the equator.

In order to obtain further light on the question of systematic errors, the simple expedient was adopted of displacing a line by a known amount, and then measuring the displacement by settings on the line itself. In this way it is possible to obtain the personal equation of any observer for lines of any width or intensity. The results indicate that a slight peculiarity in the plates may often introduce systematic errors, capable of reversing the sign of the displacement. This probably accounts for some of the discrepancies encountered in the measurement of the plates.

In spite of the fact that the results obtained are precisely such as the existence of a magnetic field would lead us to expect, and the apparent impossibility of attributing them to any other cause, some difficulties remain unexplained. A long series of photographs, made in the second order in May and June, has been measured by Dr. VAN MAANEN with the parallel plate micrometer. The second order was chosen because of the greater sharpness of the solar lines, but it is doubtful whether this policy was a wise one. The displacements on these photographs are much smaller than those of the first series, though it is extremely improbable that the strength of the Sun's field would change materially between the two sets of observations. As all of the photographs were made in pairs (quarter-wave plate inverted), it is possible to test the magnetic nature of the displacements. Thirty-eight pairs of plates give reversed signs for the displacements, while ten pairs do not. In view of the very small magnitude of the displacements, which rarely exceed 0.003^{mm}, the evidence is decidedly in favor of an actual reversal of sign produced by inversion of the quarter-wave plate.

I am unable to account for the greatly decreased magnitude of the displacements on these plates, unless it is due to the use of the second order spectrum instead of the third. On the average, the displacements are only about one-quarter as great (when reduced to the third order) as those obtained by Dr.

VAN MAANEN for the first series of plates. In this connection, and as a necessary check on all of the observations, a careful study has been made of the elliptical polarization due to the reflection of the sunlight on the two silvered mirrors of the cœlostat. The polarization phenomena vary with the declination and hour angle of the Sun, but in no case do they appear to be of such a character as to influence appreciably the magnitude of the displacements.

Another series of observations is now in progress, using the third order of the grating and the 16½-inch image of the Sun given by the object-glass of 150 feet focal length. The displacements, as far as measured, are much larger than those on the second order plates, and the results clearly confirm those of the first series.

As the matter now stands, further observations will be required to prove conclusively whether or not the observed displacements are due to the Sun's magnetic field. It may be interesting to inquire, however, as to the sign of the charge and the corresponding polarity indicated by the observations already obtained. Knowing the direction of the Sun's rotation, and assuming, for example, that the field is produced by the rotation with the Sun of two opposite and equal charges distributed through the Sun's mass and contained within spheres whose radii differ slightly,[1] we may deduce the sign of the outer charge required to produce such line displacements as have been observed. This outer charge is found to be negative, which would imply that the north and south poles of the Sun agree in magnetic polarity with those of the Earth. As for the strength of the field, a knowledge of the Zeeman effect for the line in question is necessary to determine this. It happens that all of these lines are too faint in the spark to appear on our photographs, but another effort is being made by Mr. BABCOCK to observe their behavior in the magnetic field.

The investigation is being pushed forward as rapidly as possible, in view of the quiet condition of the Sun, since the appearance of sun-spots, with their very powerful magnetic fields, will tend to introduce troublesome perturbations.

December 5, 1912.

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[1] SCHUSTER, *Proceedings Physical Society of London*, April 15, 1912; SWANN, W. F. G., "The Earth's Magnetic Field," *Philosophical Magazine*, July, 1912, Vol XXIV, p. 80. BAUER, L. A., "On the Origin of the Earth's Magnetic Field," *Phil. Magazine*, September, 1912.

ASTRONOMICAL OBSERVATIONS IN 1912.

Made by TORVALD KÖHL, at Odder, Denmark.

VARIABLE STARS.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris.*[1]

Jan. 10: S $\begin{cases} < \text{f.} \\ > \text{g.} \end{cases}$
19: = g.
Feb. 8: invisible.
Mar. 8: 2 steps > f′.
10: 1 step > f′.
12: 2 steps > f′.
24: 1 step < e.
25: id.
Apr. 2: 1 step > e.
7: = d.
12: 2 steps > d.
Aug. 25: invisible.
31: id.
Sept. 7: invisible.
12: id.
Sept. 15: id.
18: id.
28: id.
29: id.
Oct. 2: id.
5: id.
8: = g.
Nov. 5: 1 step < e.
15: = e.
21: id.
28: 1 step > e.
Dec. 2: ½ step > e.
10: id.
15: $\begin{cases} \text{half way be-} \\ \text{tween d and e.} \end{cases}$
27: = d.

T *Ursæ Majoris.*[2]

Jan. 10: T invisible.
19: id.
Feb. 8: = e.
Mar. 8: $\begin{cases} < \text{a.} \\ > \text{b.} \end{cases}$
10: ½ step > a.
12: = a.
24: 2 steps > a.
25: = a.
Apr. 2: 2 steps > a.
7: = a.
12: 1 step > a.
Aug. 25: invisible.
Sept. 7: id.
12: id.
15: id.
Sept. 18: id.
28: id.
29: id.
Oct. 2: id.
5: id.
8: = g.
Nov. 2: $\begin{cases} > \text{c.} \\ < \text{b.} \end{cases}$
5: 1 step < c.
15: = a.
21: 2 steps > b.
28: 1 step > b.
Dec. 10: id.
15: = b.
27: 1 step > b.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, **12**, 56.
[2] Vide the sketch in the *Publications A. S. P.*, No. 22, **4**, 63.

W *Pegasi.*[1]

Jan. 7: W { < g. / > h.
Mar. 14: very faint.
Apr. 18: invisible.
Aug. 6: 2 steps > c.
25: = b.
31: 2 steps < b.
Sept. 7: 1 step < b.
11: = b.
15: 1 step < b.
18: { half way between b and c.
28: id.
Oct. 2: 2 steps > c.
Oct. 6: = c.
8: id.
9: id.
18: { 2 steps > d. / 4 steps < c.
Nov. 5: 2 steps > e.
8: 1½ steps > e.
15: 1 step < e.
28: 1 step < g.
Dec. 2: = f.
10: 1 step > h.
12: id.
27: 1 step < h.

SS *Cygni.*[1]

Jan. 7, 6^h: SS 1 step < h.
10, 6^h: id.
Mar. 24, 16^h: { half way between c & d.
Aug. 25, 9^h: invisible.
31, 9^h: id.
Sept. 7, 9^h: id.
11, 10^h: 2 steps < h.
12, 10^h: 3 steps < h.
15, 9^h: 1 step < h.
18, 9^h: = h.
29, 7^h: invisible.
Oct. 2, 8^h: = g.
6, 9^h: = c.
8, 9^h: { 2 steps > c. / 5 steps < b.
Oct. 9, 9^h: id.
10, 8^h: id.
18, 9^h: = d′.
Nov. 5, 6^h: very faint.
8, 10^h: 1 step < h.
28, 7^h: invisible.
29, 7^h: id.
Dec. 2, 9^h: 1 step < f.
10, 10^h: { 2 steps < b. / 3 steps > c.
12, 7^h: 2½ steps > c.
15, 5^h: { half way between c & d.
27, 5^h: = h.

Z *Cygni.*[2]

Mar. 24: Z = a.
Apr. 12: id.
16: 1 step < a.
19: ½ step > a.
May 15: 2 steps < a.
Sept. 11: 4 steps < e.
15: id.
18: invisible.
29: id.
Oct. 2: very faint.
Oct. 6: id.
18: < e.
Nov. 8: 5 steps < e.
28: invisible.
29: id.
Dec. 2: id.
10: id.
12: id.
15: = e.
27: = d.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.
[2] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 16.

U *Herculis*.[1]

Mar. 25:	U 2 steps < f.	Sept. 15:	id.
Apr. 10:	= g.	18:	id.
12:	id.	28:	id.
18:	1 step < g.	29:	id.
20:	1 step > g.	Oct. 2:	id.
Aug. 25:	invisible.	5:	id.
Sept. 7:	id.	8:	id.
11:	id.	Nov. 28:	id.
12:	id.		

S *Persei*.[2]

Mar. 24:	S very faint.	Oct. 2:	id.
Apr. 12:	id.	6:	1 step < e.
16:	invisible.	8:	id.
19:	id.	18:	1 step > e.
Sept. 12:	= f.	Nov. 5:	½ step > e.
15:	id.	29:	1 step < c.
18:	half way between f and e.	15:	= d.
		27:	= b.

Several other stars have been watched, such as Y *Tauri* (B. D. + 20° 1083), which in the first months of the year was a little brighter, in the last months a little fainter, than the star B. D. + 20° 1095. — TV *Cygni*[1] was noted April 12th and September 11th: 4 steps > d, but on August 6th: 2 step > d.

LARGE METEORS.

Fireballs have been observed from stations in Denmark on the following dates: January 29th, February 3d, 17th, 28th, March 8th, April 18th, 21st, 22d, 23d, 26th, June 5th, 6th, July 14th, 16th (two), August 28th, September 15th, October 8th. The last-named fireball was observed from fifty-five (fourteen Danish and forty-one Swedish) stations.

SHOOTING-STARS.

Shooting-stars were observed from six stations in Denmark on August 9th and 10th. At these stations seventy-eight paths of shooting-stars were mapped, and seven proved suitable for calculation, under which four fireballs were included — the meteors on July 16th, August 28th, September 15th, and October 8th. These seven meteors have given the following results:—

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[1] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 42.

[2] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 43.

From Observation.

No.	Time, P. M.				Station.	Beginning.	Ending.	Mag.	Observer.
1	[illegible] 16.	11ʰ	1ᵐ	0ˢ	Kragelund		15° + 65°		R. Jensen
					Charlottenlund		168 + 43		F. Orluf
2	Aug. 9.	10	25	45	Varde		42 + 47	1	N. H. Bossen
					Odder		93 + 82	♃	T. Köhl
3	Aug. 9.	10	38		Nordby		0 + 38	2	J. Skakke
					Odder		290 + 33	3	T. Köhl
4	Aug. 10.	10	48		Varde	58° + 53°	51 + 55		N. H. Bossen
					Jyderup	120 + 69	167 + 66	1	M. Povlsen
					Copenhagen		186 + 52.5	1	Kierulff
5	Aug. 28.	10	8		Nyborg		83 + 49		T. Vaaben
					Ringsted		159 + 58		Christensen
6	Sept. 15.	10	10		Faxe		35 + 11		Lau
					Oestermarie		280 + 33	½ ☾	J. Bögeskov
7	Oct. 8.	6	57		Mern		62 + 38		J. Larsen
					Oestermarie		145 + 54		J. Bögeskov

From Calculation.

No.		Beginning			Ending			Real length of path.	Radiant.	
		h	λ	φ	h	λ	φ	β	AR	Decl.
1					90.0	2° 19′.8 w	56° 49′.0			
2					79.1	2 21 .6 w	56 35 .8			
3					99.5	2 29 .5 w	55 36 .4			
4	A	173.6	1° 14′.3	57° 48′.9	125.5	2 10 .4 w	56 59 .3	120.1	70°	+ 49°
	B				125.5	2 9 .8 w	56 59 .7			
	C				126.9	2 11 .4 w	56 59 .7			
5					33.1	1 7 .5 w	56 1 .0			
6					54.8	1 48 .1 e	55 0 .8			
7					61.5	1 51 .6 e	56 27 .8			

h and *β* are expressed in kilometers; λ is longitude from Copenhagen; φ is north latitude; *h* is the altitude of the meteor above the Earth's surface. The combination of Varde-Jyderup is marked *A*, Varde-Copenhagen *B*, and Jyderup-Copenhagen *C*.

The attempt has been made to calculate the *true diameter* of meteor No. 6, with 126 meters as the result.

My Meteor-Catalog has now reached a number of 5,533 meteors, observed from stations in Denmark and surrounding countries from 1875 to 1812, inclusive.

From August 12th to 17th, inclusive, astronomical lectures were held at the Carina Observatory in Odder. In the estimation of variable stars I often have been assisted by Mr. J. Skakke.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1913.

By Malcolm McNeil.

PHASES OF THE MOON, PACIFIC TIME.

New Moon	Mar. 7,	$4^h 22^m$	P.M.	New Moon	Apr. 6,	$9^h 48^m$	A.M.
First Quarter.	" 15,	12 58	P.M.	First Quarter.	" 13,	9 39	P.M.
Full Moon	" 22,	3 56	A.M.	Full Moon	" 20,	1 33	P.M.
Last Quarter	" 29,	4 58	A.M.	Last Quarter	" 27,	10 9	P.M.

The first of the eclipses of the year, a total eclipse of the Moon, will occur on the night of March 21st-22d, the beginning visible generally in North America, western South America, throughout the Pacific Ocean, Australia, and the eastern border of Asia; the ending visible generally in western North America, the Pacific Ocean, Australia, central and eastern Asia.

CIRCUMSTANCES OF THE ECLIPSE, PACIFIC TIME.

Moon enters penumbra	March 22,	$1^h 16^m$	A.M.
Moon enters shadow	" 22,	2 13	A.M.
Total eclipse begins	" 22,	3 11	A.M.
Middle of the eclipse	" 22,	3 58	A.M.
Total eclipse ends	" 22,	4 44	A.M.
Moon leaves shadow	" 22,	5 43	A.M.
Moon leaves penumbra	" 22,	6 39	A.M.

The second eclipse, a partial eclipse of the Sun, will occur on April 6th. It will be visible throughout the regions near the North Pole, Alaska, western British America, and the extreme western part of the United States to a point a little south of San Francisco. In the United States and southern Alaska it will be an early morning affair. The American Ephemeris computes the times for Sitka, and gives beginning April 6th, $7^h 35^m$ A. M., and ending $9^h 17^m$ A. M., local mean time, which is almost exactly one hour slow of Pacific time. The maximum obscuration of the Sun is less than one half of its diameter.

The vernal equinox, the time when the Sun crosses the equator from south to north, occurs March 20th, 9 P. M. Pacific time.

Mercury is in fine position for evening observation in early March. On March 1st it sets an hour and three quarters after sunset and the interval remains as great as an hour and one half until about the middle of the month. After that it shortens up very rapidly. The planet reaches greatest east elongation on March 10th. As the planet passed its perihelion only four days earlier, the apparent distance from the Sun, 18° 14′, is much smaller than the average greatest elongation, but it passes the most northerly point in its orbit on March 16th, and it is then more than 9° north of the Sun; so the interval between sunset and the setting of the planet is materially increased. After the middle of the month *Mercury* approaches the Sun very rapidly, passing inferior conjunction and becoming a morning star on March 27th. It reaches greatest west elongation, 27° 12′, on April 24th. This is much larger than the average greatest elongation, as the planet passed its aphelion on April 19th, only five days before; but the planet is now 12° south of the Sun, and the interval between the rising of the planet and that of the Sun scarcely reaches an hour. The conditions for visibility are therefore very poor.

Venus is in fine position for evening observation, setting about four hours after sunset on March 1st and about three hours after on April 1st. After that it approaches the Sun very rapidly and reaches inferior conjunction, becoming a morning star on April 24th. It will then remain a morning star until February 11, 1914. Its eastward motion among the stars gradually diminishes until April 2d, when it becomes stationary, and then moves westward until May 13th. The entire retrograde motion is about 14°. It passes perihelion on March 3d, but the orbit is so nearly circular that this makes very little change in its appearance to us, being in this respect very different from *Mercury* and *Mars*. On March 19th it is at its greatest brightness, being then about half-way between greatest elongation and inferior conjunction; and for some weeks before and after that date it will be visible to the naked eye in full sunlight.

The apparent distance of *Mars* from the Sun is gradually increasing, so that it has now become an easy object to see in the early morning. On March 1st it rises not quite an hour and a half before sunrise, and this interval increases about a quarter of an hour during the two months' period. Its actual distance from the Earth diminishes about twenty-five million miles, and its brightness increases materially, being at the end of April about twice as great as it was on January 1st, although still only 15 per cent as bright as it will be at the next opposition in January, 1914.

Jupiter is gradually drawing farther away from the Sun, and rising earlier, at about three hours before sunrise on March 1st, and at about midnight on April 30th. During the two months' period it moves about 5° eastward in the constellation *Sagittarius,* north and a little east of the "milk dipper."

Saturn is still in good position for evening observation, although it sets much earlier than it did at the beginning of the year. On March 1st it sets shortly after midnight, and at the end of April somewhat before nine o'clock. It moves about 6° eastward and a little northward in the constellation *Taurus,* between the *Pleiades* and the *Hyades* groups. The rings keep about the same opening as during the early part of the year.

Uranus rises shortly five o'clock in the morning in early March and shortly after one at the end of April. It is in the constellation *Capricorn* and moves about 2° eastward during the month.

Neptune is above the horizon until after midnight. It is in *Gemini* south of *Castor* and *Pollux,* the principal stars of the constellation.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE ORBIT OF THE SHORT-PERIOD BINARY STAR A 88.

The double star A88 (R.A. = $18^h\ 33^m\ 19^s$; Decl. = —3° 17′; magnitudes = 7.2, 7.2; spectral type = F 8) was discovered by the writer with the 36-inch telescope in 1901. Measures on three nights gave the position:

1901.56 338°.3 0″.14,

and the mean of measures on three nights in the following year was found to be:

1902.66 318°.1 0″.12.

The rapid motion indicated by these results led me to measure the pair annually. The observed angular motion has continued to be rapid, averaging almost 30° per year, and the position of the companion is now nearly the same as at the time of discovery. Three nights' measures in the present year give the position:

1912.57 356°.1 0″.15.

The data for an approximate orbit are thus available, and from them I have derived the following system of elements, using graphical methods:

P = 12.12 years
T = 1910.10
e = 0.273
a = 0″.176
☊ = 2°.4
i = ± 62.4
ω = 270.0
Angles decreasing

Measures of the apparent ellipse give the values:

Length of major axis = 0″.337
Length of minor axis = 0 .163
Distance of star from center = 0 .022
Position angle of major axis = 1°.9
Position angle of periastron = 92.4

The pair is always difficult to measure, even with the 36-inch refractor, for the maximum distance between the components is only 0″.17, the minimum value being 0″.07. For this reason, probably, measures have not been made, so far as I am aware, by any other observers, and my orbit necessarily rests entirely upon my own observations.

The elements given are to be regarded as preliminary only, but the general form of the apparent ellipse is well defined. The orbit represents my measures as well as could be expected in a pair of this character, the residuals in distance falling within the limits ± 0″.03, and the residuals in angle, reduced to arc measure, being considerably smaller (except for the year 1904, for which the residual is 0″.05).

Only three other visual binary stars—*δ Equulei*, 13 *Ceti* and *κ Pegasi*—are known to have shorter periods of revolution than that found for A 88.

R. G. Aitken.

December, 1912.

Position of Nova Geminorum, 1912.

Two observations of last year's *Nova* made with the meridian circle on January 27th and 29th, give the position referred to mean equinox 1913.0:—

R. A. $6^h\ 49^m\ 15^s.773$; Decl. $+32^\circ\ 15'\ 1''.64$; Epoch 1913.08.

Two observations were obtained last year, immediately following the receipt of the announcement of discovery in March. Referred to mean equinox 1912.0, the position was:—

	$6^h\ 49^m\ 11^s.796$;	$+32^\circ\ 15'\ 5''.63$;	Epoch 1912.22
Precession	+ 3.896	— 4.27	
1913.0	15.692	1.36	

Comparison of the results, differing ten months in epoch, gives no indication of change of position. The drop in brightness, from fifth magnitude in March, 1912, to eighth magnitude now, would produce an effect upon the observed transit of the *Nova* of about one third of the right ascension difference, due to magnitude equation (three units at $0^s.008$), and the outstanding differences are not greater than might be due to probable errors of observation.

R. H. Tucker.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these Publications, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to keep [illegible] published criticisms, favorable or unfavorable, to a minimum.

A New Form of Interferometer.

In the October number of the *Zeitschrift für Instrumentenkunde* Dr. F. Goos describes a new, simple and inexpensive form of the Fabry-Perot interferometer. In the usual form of this instrument the device for securing parallelism of the half-silvered plates is rather complex, and the instrument is very sensitive to vibration, so that an isolated pier is necessary. These precautions are not necessary with the improved form, which is a rigid whole. The glass plates are carried in a horizontal instead of in a vertical position. The base, carrying the lower plate, is a massive three-legged spider, the three feet being at the vertices of an equilateral triangle about ten inches on a side. Three fairly good micrometer screws, of half-millimeter pitch, screw into the three feet; on these screws rests the upper plate carrier. The screws are provided with large divided heads; these are divided into one hundred parts, and a movement of one division changes the parallelism of the plates by 4″.5 of arc. Finer screws or larger spiders would give still greater sensitiveness. The instrument is easy to adjust, vibrations have very little effect, and it would be easy of construction with the facilities of an ordinary laboratory.

H. D. C.

On the Staining of Photographic Plates.

The methods of staining photographic plates introduced by Professor Wallace, by enabling astronomers and physicists to photograph the red end of the spectrum without difficulty, have caused great advances to be made in certain lines of astrophysical work. Where relative intensities are desired, however, it seems that the method must be used with great care. This aspect of the subject is dealt with in a suggestive paper by Professor V. M. ARCICHOVSKY, in Vol. I, No. 17, of the *Ann. de l'Inst. Polyt. à Nowocherkassk.* The paper is entitled "On the Search for Chlorophyll on the Planets," and is in Russian, with a résumé in German at the end. A number of investigators have considered the possibility of deriving, by spectrographic means, evidence as to the existence on the planets of Chlorophyll, so characteristic of terrestrial vegetation. With this phase of the subject the present paper has very little to do; it is rather a study of the staining methods used for sensitizing plates to the red rays. A large number of tests of the effects of pinacyanol, pinaverdol, and dicyanin were made with short exposures; some were made on the Sun and others on a Welsbach burner. The effect of the various dyes was determined separately, and also in various combinations; in particular, a number of tests were made using the same dyes and the same manipulation as used by SLIPHER in securing his well-known spectrograms of *Uranus* and *Neptune*. The sensitiveness of plates stained with any or all of these dyes is quite irregular, absorption bands showing clearly with short exposures. ARCICHOVSKY comes to the conclusion that SLIPHER'S results on *Uranus* are really a combination of the planet spectrum with those effects due to the irregular sensitiveness of the plate stained by his method. The cuts show quite conclusively that the dark band between B and C, in particular, in SLIPHER'S spectrum of *Uranus* can be secured in spectrograms of the Sun or the Welsbach burner on plates stained in this way. While not all of the bands in the spectrum of *Uranus* can be thus reproduced, Professor ARCICHOVSKY'S results are suggestive and valuable, and emphasize the need for further studies in this field before complete confidence can be felt in investigations involving short exposures on plates stained for sensitiveness in the red end of the spectrum. H. D. C.

A CONTRIBUTION TO OUR KNOWLEDGE OF STELLAR DISTANCES.

Parts III and IV of Volume II of the *Transactions of the Astronomical Observatory of Yale Observatory* have just been published and form a fitting continuation of the valuable work which has been carried on at this institution in the determination of stellar distances by means of the heliometer. Determinations of the parallax of forty-one southern stars north of — 13° declination and a catalogue of all parallax determinations made at Yale are included in the volume.

The stars selected were, for the most part, those of large proper motion. The average probable error is ± 0″.017. This is very small and stamps this series as more accurate than any other extended list of heliometer determinations. It should be noted here that this average probable error is almost as small as that of the very best modern photographic parallaxes, for it is but very little larger than the average probable error of ± 0″.013 secured by SCHLESINGER. If this record could be maintained, the heliometer would take its place as fully the equal of the best photographic determinations with long-focus instruments. For all the Yale heliometer results the probable error in 245 determinations averages ± 0.″030, while the average of a large number of old and modern heliometer determinations is ± 0″.035.

Three stars in this list have large parallaxes. These are *ε Eridani*, 0″.31 ; *δ Eridani*, 0″.18, and *Weisse* 16^h 906, 0″.21, placing these stars in the list of our nearer stellar neighbors. Of the forty-one stars, ten, or nearly one-fourth, show negative parallaxes (three of these, it is true, being bright stars without sensible proper motion included in the list). Modern ideas of the stellar universe premise a scale of distances far more vast than was held twenty years ago, and this proportion of negative parallaxes tends to inspire a feeling of confidence in the Yale results rather than otherwise. That so excellent a series, based upon stars of large proper motion most likely, *a priori*, to be among our nearer neighbors, should show this proportion of negative parallaxes, brings home to us, however, the insurmountable character of the wall which bars our progress. It is becoming increasingly more evident that the best modern methods, whether heliometer or long-focus photographs, can do little more than to pick out some of our nearer neighbors. A combination of radial velocity and proper-motion data has already given us trustworthy results for the average distances of the brighter stars several times more remote in space than the limit given by the direct methods. The radial velocity method will undoubtedly extend our measurable universe still farther in the next half-century, but even in this method we can discern the barrier ahead beyond which we cannot pass, for the era of position observations on the fainter stars is too short to determine accurately their minute proper motions, and the radial velocities are too difficult to secure. What will be the new methods of determining the size of our universe, or will the present barriers always stand? H. D. C.

A POSSIBLE ABSORPTION OF GRAVITATIONAL ENERGY.

One of the most interesting subjects discussed in recent astronomical literature is that of a possible absorption of gravitation by a body situated or passing between the two bodies whose mutual attractions are in question. Important papers have been published by Dr. K. F. BOTTLINGER, in a preliminary way in the *Astronomische Nachrichten* of April 21, 1912, and more completely a little later as a prize dissertation of the University of Munich, in pamphlet form; and likewise by Professor DE SITTER in the November number of *The Observatory.* Professor DE SITTER recalls attention to the remarkable fact that thus far no satisfactory physical explanation has been found for the existence or nature of gravitation. He quotes from his paper dated 1908 to the effect that the explanation must be sought "in its extreme simplicity, its complete independence of everything that affects other phenomena of nature. Gravitation is not subject to absorption nor refraction, no velocity of propagation has been ascertained, it affects all bodies equally without any difference, always and everywhere we find it in the same simple and rigorous form, which defeats all attempts to penetrate into its inner mechanism."

In 1909 Professor SEELIGER proposed a new point of view concerning gravitational attraction, as follows (a free translation): "The entering of a third body between two other bodies must influence the normal attraction of the two bodies upon each other and show departures from the Newtonian formula, which one may perhaps describe as absorption of gravitation. Such departures, which in themselves seem quite plausible, have perhaps first to establish themselves by discovery. They may eventually be discoverable in the motion of the Moon—and perhaps only in the lunar motion."

Shortly thereafter BOTTLINGER, a student of SEELIGER'S, undertook the investigation of the question whether the gravitational pull exerted by the Sun upon the Moon is during a lunar eclipse diminished by a small fraction of its amount, dependent upon the mass of the Earth which is traversed, so to speak, by the lines of solar gravitational force which would reach the Moon. As a starting-point, BOTTLINGER assumed that the interposition of the Earth would reduce the effective solar attraction upon the Moon by a function of the Earth-mass traversed, and computed the variations in lunar longitude which should have resulted in consequence of the lunar eclipses from 1834 to 1909.

Almost simultaneously and before BOTTLINGER'S results were published, DE SITTER had carried through similar investigations and computations. The results of the two investigators are not in strict accord, though their curves of longitude disturbances have many points in resemblance. Both investigators were interested to determine whether the unexplained discrepancies between observed and predicted longitudes of the Moon, as published by Professor NEWCOMB, could have their explanation in this absorption of gravitational force. In brief, the discrepancies announced by NEWCOMB are not satisfactorily explained on this basis; but on account of the computational difficulties, and of uncertainties as to the form of the absorptive function and the distribution of mass within the Earth, no one can safely say that the absorption of gravitation during lunar eclipses is not the important factor. We can only say that the problem remains as yet unsolved, because of the difficulties and uncertainties inherent in its nature.

W. W. CAMPBELL.

NOTES ON THE PROBLEM OF LATITUDE VARIATION.

Nature for December 26, 1912, abstracts an interesting and instructive article on the relationship of latitude variations and mean sea-level variations in Japan, as published in the Japan

Astronomical Herald by Dr. OMORI, the seismologist. Studying the mean sea-level records for nine stations on the Japanese coast, he finds that average sea-level was low in 1897 and 1902, but was high in 1899 and 1905. The greatest fluctuations seem to have occurred at Misaki, near Yokohama, where the mean sea-level, constant in 1897, was 166 millimeters higher by 1909. Plotting the mean results for the nine stations, and likewise the latitude variations as observed at Tokyo and Mizusawa during the same period, OMORI observed that the curves for the two phenomena have striking resemblances, from which it appears that a variation of 0″.1 in latitude was accompanied by the change of 42 millimeters in sea-level. These results are very suggestive of promising investigations along the same lines, based upon voluminous existing records of mean sea-level at many coastal points throughout the civilized world.

The *Comptes Rendus* of the Paris Academy of Sciences for October 14, 1912, publishes an interesting account of the Hamburg meeting of the International Geodetic Conference last September. We note with regret that a shortage of financial resources makes it necessary to reduce the number of International Latitude stations. The high efficiency shown in the administration of this special latitude service and the fruitfulness of the results bring instant regrets that a curtailment of the service is even considered. The account does not state which stations are to be closed, but I learn from another source that the station at Gaithersburg, Md., has been instructed to bring its work to a conclusion in the immediate future.

Dr. F. E. Ross, who has been the Gaithersburg observer for several years past, has recently made an important contribution to the latitude variation question, notwithstanding that his conclusion is of a negative character. The so-called Kimura term in the latitude variation has seemed to imply that the effective center of mass of the Earth shifted northward from its mean position to the extent of three or four feet every northern winter season and correspondingly southward from its mean position three or four feet every southern winter season. Dr. Ross's thorough-going paper on the subject lends strong support to his belief that the insufficiency of the formulæ upon which the computations have been based is responsible for the greater part of the apparent Kimura annual variation. I understand Dr. Ross's point of view to be that the entire term may be due to this cause, and that the Kimura variation may have no objective existence. W. W. Campbell.

CONTRIBUTIONS TO THE LABORATORY SPECTRUM OF HYDROGEN.

Nature for December 26, 1912, describes briefly some extremely important results on the hydrogen spectrum secured by Professor Alfred Fowler of South Kensington.

Taking up the subject chonologically, we begin naturally with the Harvard College Observatory's announcement in 1896 that a new series of absorption lines, six in number, had been found in the spectrum of *Zeta Puppis*, which are apparently in intimate relationship with the well-known lines in the spectrum of hydrogen. Later spectrograms of the same star brought the number of lines in the new series up to eight, in 1897. Professor Pickering was able to construct a formula of relationship between wave-lengths and a variable, *n*, such that by substituting successive integral numbers for *n* the resulting values of the wave-lengths were those of all the lines in the well-known hydrogen spectrum and of all the lines in the new series. He therefore concluded that the newly found lines belong to the spectrum of hydrogen. Further interesting questions as to the relationship of the old and new lines were discussed by Kayser and by Rydberg, but upon these we need not comment here except to say that Rydberg's formula predicted the existence of additional hydrogen lines at wave-lengths 4688, 2735, 2386, 2254 and 2188.

Fowler's recent study was of the spectrum obtained by passing a strong electric discharge through an ordinary Plücker tube containing a mixture of hydrogen and helium. In particular, he observed lines at wave-lengths 4686, 2733, 2385 and 2253, which are unquestionably the first four of the five lines predicted by Rydberg.

Other lines observed by Fowler agree well with three lines which the Harvard College Observatory had found in the spectrum of *Zeta Puppis*.

Three other strong lines observed by Fowler, at wave-lengths 3203, 2511 and 2306, are said, according to the report, to belong to the hydrogen spectrum.

It is of especial interest to note that none of these ten lines were apparently observed by FOWLER except when he was dealing with hydrogen and helium combined; another illustration of the apparent principle, to which several observers have called attention, that the spectrum of an element may be affected by the presence of another element.

Such additions to our knowledge as that made by FOWLER frequently have applications to celestial spectroscopy so wide that one cannot foresee the limits. W. W. CAMPBELL.

GENERAL NOTES.

Death of Dr. Lewis Swift.—It is with great regret that we record here the death of this veteran astronomer on January 5th at his home in Marathon, New York. Dr. SWIFT lacked but a few weeks of being ninety-three years of age; he was born at Clarkson, New York, on February 29, 1820. As an astronomer and scientist, Dr. SWIFT was largely self-educated. When a young man he became greatly interested in scientific matters, and devoted himself for some time to the lecture field, traveling about and lecturing upon electricity, then a comparatively new subject. He afterwards entered the hardware business, but found time to continue his astronomical work at the same time, discovering several comets. Moving to Rochester, he set up his small telescope on the roof of an old cider mill, and his cometary discoveries attracted the attention of H. H. WARNER, a wealthy manufacturer of proprietary medicines. Mr. WARNER built for Dr. SWIFT the Warner Observatory, in which was installed an 18-inch refractor, whose cost was met by popular subscription by the citizens of Rochester. Financial reverses later compelled Mr. WARNER to withdraw his support, and Dr SWIFT then took this telescope to the Lowe Observatory, in Southern California, where he remained till failing eyesight compelled him to withdraw from all astronomical work.

Dr. Swift discovered fourteen comets and over thirteen hundred new nebulæ, and it is from his work in these fields that his name is best known. He was one of the very few astronomers who have had the privilege of seeing Halley's Comet at two successive apparitions. He was a Fellow of the Royal Astronomical Society, and was the recipient of numerous medals for his cometary discoveries. He was almost entirely deaf, but overcame this obstacle to his scientific work with characteristic ingenuity by placing a small induction coil in circuit with his clock, so that at each tick a slight shock was sent through his arm. His last years were spent in retirement from all active duties, at the home of his daughter in Marathon Though both hearing and sight had now failed him, he never ceased to manifest a keen interest in the progress of his favorite science.

Eclipses in 1913.—There will be three solar eclipses in 1913. but all of them will be partial eclipses and of no particular interest astronomically. These partial eclipses will take place on April 6th, August 31st, and September 29th. For the eclipse of April 6th, the eclipse area extends just south of San Francisco, but the amount of obscuration will be too slight to be noticed without telescopic aid. The other two will not be visible at all from the United States. There will be two total lunar eclipses. That of March 21st-22d will be visible in California, the middle of the eclipse coming a few minutes before 4 A. M. on the morning of the 22d. The beginning of the lunar eclipse of September 14th-15th will be visible in California, but not the total phase.

The trustees of Wesleyan University have voted to build an astronomical observatory at a cost of $60,000.—*Science,* November 15th.

The next meeting of the International Union for Solar Research will be held at Bonn, beginning August 1, 1913. The Astronomical and Astrophysical Society of America will hold no summer meeting in 1913, because of the probable absence of a number of its members at the Bonn conference. The summer meeting of 1914 will be held at Northwestern University, and that of 1915 in San Francisco and at the Lick Observatory.

The great 100-inch disk of glass for Mount Wilson was at first rejected because of flaws. After a number of attempts to secure a more perfect disk of the requisite thickness had failed, it was decided to make the attempt to figure and polish the disk on hand. We learn from *Popular Astronomy* that recent tests unfortunately show that this disk is probably useless, as was feared, and the completion of the great reflector seems therefore to be only a hope of the distant future, depending on the securing of a more perfect disk of glass. It is said that a perfect disk eight inches thick has been cast, but this is believed to be relatively too thin to promise a successful mirror. The casting and proper annealing of so great a disk appears to be fully as difficult a matter as in the case of great lenses.

There are at least four or five large lenses which have now been delayed a year or more awaiting the successful casting of the glass disks. It will be remembered that there were at least nineteen failures before the crown glass disk for the Lick refractor was secured.

Dr. C. D. PERRINE, director of the National Observatory at Cordoba, Argentina, has placed orders with the Alvan Clark & Sons Corporation for a 24-inch, a 12-inch and several other objectives.

Professor M. ANDOYER, of the Nice Observatory, has been chosen to succeed POINCARÉ in the professorship of mathematical astronomy at the University of Paris.

On January 6th and 7th a cold wave struck California which was responsible for the breaking of many low-temperature records throughout the State and did considerable damage to citrus fruits. At Mount Hamilton the weather was marked by perfectly clear skies, with a north wind of from forty to sixty miles per hour and a minimum temperature of 11°.5 Fahrenheit, which is believed to be the lowest temperature ever recorded at the observatory.

An International Time Conference was held at Paris in October, to which delegates were sent by the principal governments of the world. The subjects discussed by the four commissions, into which the conference was divided, were as follows:—

1. The astronomical determination of time, and the correction of time-keepers.
2. Radio-telegraphic transmission of time. Apparatus to be used for sending and receiving hourly signals.
3. The degree of precision that ought to be reached in the hourly signals for different purposes; for astronomy and geodesy, navigation, meteorology, seismography, and various scientific applications; for railways, public administration, and clock-makers.
4. Collaboration of different astronomical centers to insure the best knowledge of time.

Consideration of the general organization necessary to provide for the transmission as well as the reception of hourly signals, so as to satisfy all wants.

International meteorological telegrams.

A scheme was put forward to be submitted to the governments represented for the establishment of a "Commission Internationale de l'Heure," with an executive "Bureau Internationale de l'Heure" located at Paris. It was agreed:—

1. To use Greenwich time;
2. To send out the signals at exact hours;
3. To arrange that there shall be no overlapping.
4. To determine the most suitable wave-length to be employed.

As to the sending of the signals, it was proposed that signals should be sent by radio-telegraphy from stations around the globe, so chosen that any place on the Earth should be able to receive a day signal and a night signal. Nine such stations have been selected, and the time for sending out signals determined, each signal extending over three minutes before the end of some hour by Greenwich time.

Sir George Howard Darwin.[1]—Science is the poorer, and especially that branch of it in which Englishmen since NEWTON'S days have held a prominent position, astronomical physics, by the death of Sir GEORGE DARWIN, K.C.B., F.R.S., D.SC., LL.D., the Plumian Professor of Astronomy at Cambridge. Sir GEORGE, who underwent a serious operation two months ago, passed away on December 9th.

Sir GEORGE DARWIN was the distinguished son of a most distinguished father. CHARLES DARWIN, prince of naturalists, died in 1882, honored in every land where science is cultivated, but untitled in his own. He left five sons—WILLIAM ERASMUS, GEORGE HOWARD, FRANCIS, LEONARD, and HORACE, and two daughters. It is the second of these sons, GEORGE HOWARD, who has now passed away. Of his family, all of them intellectual and scientific, GEORGE HOWARD least resembled his father in his favorite studies and research. CHARLES DARWIN used to confess with regret his ignorance of mathematics. That was not much for one who was equally ready to profess deficient knowledge of botany, of which he might have been a professor in any university, but in the case of mathematics it was perhaps true. He declared, indeed, that he never understood an equation, and he deplored the ignorance because that science seemed to endow men with a special faculty. His son, now no more, was one of the great mathematicians of his day, who, curiously enough, used to say that he knew very little of those biological studies which his father had enriched for all time.

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[1] From the *London Daily Telegraph.*

GEORGE HOWARD DARWIN was a native of Down, in Kent, that pretty, antique village, whither naturalists from the ends of the Earth resort to see the place where the "Origin of Species" was written. The house is still there, but it is, we believe, now a ladies' school. There, on July 9, 1845, the future mathematical physicist was born. Except in scientific circles his father was little known, save perhaps as the author of the "Voyage of the Beagle," and few of those who then read that wonderful book could have any idea how great a work it was.

When only 23 years of age GEORGE granduated Second Wrangler and Second Smith's Prizeman. He was thus among the list of the greatest physicists of the nineteenth century who were Second Wranglers—Lord KELVIN, CLERK MAXWELL, and J. J. THOMPSON among them. In the same year he was elected Fellow of his college. Curiously enough, he became a barrister in 1874, recalling the fact not generally known that the greatest of the world's mathematical physicists narrowly escaped being a lawyer. When ISAAC NEWTON came to London he was poor. On account of that poverty he offered to resign his fellowship of the Royal Society, but the good secretary OLDENBURG discerned the reason and "Mr. NEWTON's" annual fee to the Royal Society was remitted. He had serious thoughts of becoming a lawyer. Presently he became Lucasian Professor at Cambridge; his "bread and cheese" were secured, and the world of science was spared a disaster.

In the year 1883 GEORGE DARWIN was elected Plumian Professor of "Astronomy and Experimental Philosophy" at Cambridge.

GEORGE DARWIN had already, at the date of his succession to the professorship, done good work. In 1880 he had traced back, by a process of abstruse reasoning, the history of the Moon and its relationship to the Earth, and demonstrated that in all probability there was a time when the Earth-Moon system was one body, and that a crisis came when the Earth—not then the rigid body it is now, but rotating much more rapidly—threw off a part of its substance into space and so formed our satellite. When that event happened there started the species of attraction between the two bodies which, in its widest and most generalized sense, is known as "tidal."

The theory of the tides and its application not merely to the great oceans of our own globe, but still more to stellar worlds—some of which are still in their earlier stages of existence—have been, perhaps, the crowning work of the great physicist now no more. It belongs to the romance of scientific speculation, to the most sublime of astronomical hypotheses.

RIGIDITY OF THE EARTH.

One of the difficulties in the problem of the tides arises from the rigidity of the Earth. We know that the waters of the ocean rise and fall in obedience to tidal attraction; yet few people realize how many hundreds of millions of tons of water every day enter the English Channel, the North Sea, the Thames, and Severn, and all our other seas and estuaries—to say nothing of the great oceans, through the pull of the Moon's attraction. Does the solid surface of the globe itself yield to the same force? This is a question still unanswered. The late Lord KELVIN and Sir GEORGE DARWIN studied this problem profoundly. They came to the conclusion that our solid globe must be, as a whole, as rigid as glass or steel, otherwise visible earth-waves due to tidal gravitation would be formed on its land surfaces. It is now generally believed that the Earth does yield slightly to these tidal forces, and this hypothesis has been brought forward as a possible contributing cause of earthquakes, but so far without confirmatory evidence. Sir GEORGE and Lord KELVIN came to the conclusion that "the effective rigidity of the Earth must be greater than that of glass—and probably as great as that of steel." An old theory of some geologists assumed that the Earth was practically a hollow sphere with a solid crust. Sir GEORGE DARWIN's researches corroborated those of KELVIN that this condition was impossible. The Earth is five and a half times as heavy as a globe of water of the same size—as that wonderful recluse, HENRY CAVENDISH, proved in 1798—and could not conceivably be hollow, and besides the idea conflicted with the tidal theories.

AGE OF THE WORLD.

Although a great mathematician and a strong physical reasoner, Sir GEORGE DARWIN had the merit to bear in mind that, as HUXLEY said, what comes out of the mathematical mill depends largely upon what you put into it. The physicist cannot always be certain of his data. Hence he did not commit himself to KELVIN's theory that the Sun's heat could not have lasted more than a hundred million years, for he saw well enough the reasonableness of the demand of geologists, like his father, for a much longer period. Time justified the caution. Madame CURIE discovered radium. In radium we saw the breaking up of an element, and the evolution of heat-energy never before dreamed of.. The geologists won, and now they can have the two hundred million years or more that long ago they deemed necessary.

In regard to another theory, Sir GEORGE DARWIN's calculations were of service to geologists. What caused the Glacial Epoch? No physical problem is of deeper interest in the story of the Earth. One favorite solution was that the pole of the Earth had changed its place in past times. There were certainly periods when plants grew near the North Pole and near the South Pole, sufficient by their remains to form beds of coal, where to-day there are never-melting ice-caps hundreds of feet thick But if the poles were not then where they are now, what produced the change? It was suggested that greater accumulations of ice at various times within the polar circles affected the world's gravitation, and shifted the position of the Earth's axis. Sir GEORGE DARWIN proved mathematically that no such distribution of weight would account for a movement of the world's axis, except under other simultaneous conditions, which are practically out of the question, and so the glaciation periods remain unaccounted for.

Researches like those of the late Plumian professor appeal to comparatively few. Such papers as "Harmonic Analysis of Tidal Observations," or the application of spherical harmonics "to determine the stresses caused in the interior of the Earth by the weight of continents and mountains," are beyond most physicists. They engaged GEORGE DARWIN thirty years ago. It would be a mistake to suppose because they seem to-day in some cases of theoretical value only, they are of no practical service. So seemed CLERK MAXWELL's electro-magnetic theory of light forty years ago. It is now the basis of wireless telegraphy. In the sublime field of astronomy GEORGE DARWIN helped the advancement of the theory of evolution in the making of worlds, as his noble father did in the development of organic life.

Robert Gauss.—ROBERT GAUSS, grandson of KARL FRIEDERICH GAUSS, the most distinguished mathematician of the last century, died in Denver on Sunday, January 19th. He had been editorial writer on the Denver *Republican* staff for the past twenty-nine years, and was a man of wide culture in historical and scientific subjects, and a most kindly and lovable character. He had given much time to experiments upon the growth and selection of grains and vegetables under semi-arid conditions of development, and a bill is now before Congress for the establishment of an agricultural station in Colorado to continue the research which he had carried on entirely from his own funds.

He was 61 years of age, and the son of EUGENE GAUSS, formerly of St. Louis. His brother, CHARLES HENRY GAUSS, of St. Charles, Missouri, died within a few hours of ROBERT GAUSS, both brothers from the same cause, heart disease. A sister and two brothers survive them. There are also cousins in this country, descendants of the great German mathematician.

The Lick Observatory possesses a portrait of KARL FRIEDERICH GAUSS, presented by the grandson, ROBERT GAUSS, nearly twenty years ago. There is also a framed autograph letter in our collection, written by the grandfather in 1844 to his son EUGENE, who was married in this country in that year. The letter had been carefully treasured by ROBERT GAUSS until he gave it to the observatory for preservation. R. H. T.

ADDENDUM TO THE MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON NOVEMBER 30, 1912, AT 2:00 P. M., TO CONSIDER THE AWARD OF THE BRUCE MEDAL FOR THE YEAR 1913.

There were present President H. D. Curtis and Directors Aitken, Townley, Crawford, Costa, and Richardson.

The proxies of Directors Hale, Campbell, Cushing, and McAdie were held by Aitken, Curtis, Richardson, and Crawford, respectively.

Nominating communications were read by the Secretary from the directors of the observatories of Harvard, Lick, Yerkes, Greenwich, and Paris.

After careful consideration of the merits of the various nominees and a frank discussion of the policy which actuates the Society in the bestowal of this medal, a ballot was taken, resulting in the selection of Professor J. C. Kapteyn, of Groningen, Holland, as Bruce Medalist for the year 1913, by the unanimous vote of ten Directors, as follows: H. D. Curtis, R. G. Aitken, R. T. Crawford, S. D. Townley, J. Costa, D. S. Richardson, W. W. Campbell,* Geo. E. Hale,* Chas. S. Cushing,* and Alex. G. McAdie.*

* By proxy.

In view of the change in the date of the annual meeting from March to January, at which meeting it is customary to review the life and career of the recipient of the Bruce Medal, a resolution was passed by the Board, suspending those provisions of the By-Laws which fix a date for the notification of the recipient and instructing the Secretary to notify Professor Kapteyn at once and proceed without delay to secure the medal from Paris. It was hoped, by this means, to have both the acceptance of Professor Kapteyn and the engraved medal back in time for the January meeting.

D. S. Richardson,
Secretary.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, 748 PHELAN BUILDING, SAN FRANCISCO, ON JANUARY 25, 1913, *at* 7:15 P. M.

President H. D. Curtis in the chair. There were also present Directors R. T. Crawford, A. G. McAdie, Charles S. Cushing, J. Costa, and D. S. Richardson.

The minutes of the previous meeting were approved as printed.

A communication was received from Charles S. Cushing, requesting that he be elected to Life Membership in the Society, which was done.

The name of Mr. James K. Lynch was proposed by Director Cushing for membership and favorably acted upon.

Following a general discussion of the finances of the Society, showing that some $6,000 of its assets are being carried in bank and earning bank interest only, a motion was made by Director Cushing and seconded by Director Costa, authorizing the Finance Committee, in cooperation with the President, to invest, in their discretion, from two to three thousand dollars of the Society funds in interest-bearing bonds of approved security.

The resolution was carried by unanimous vote.

There was some discussion as to the necessity of increasing the amount of fire insurance now carried on the Library of the Society, but the conclusion was finally reached that the present amount of one thousand dollars was sufficient for the present.

Informal instructions were given the Secretary to interview the proprietors of the Phelan Building, with a view to ascertaining if a larger room for the use of the Society may not be obtained for the same rental now paid.

Adjourned. D. S. Richardson,
Secretary.

Annual Meeting of the Astronomical Society of the Pacific, Held on January 25, 1913, in the Assembly Hall of the Phelan Building, San Francisco, at 8:00 P. M.

The meeting was called to order by President H. D. Curtis. The minutes of the previous annual meeting, as printed in the *Publications* of April, 1912, were approved without reading.

The chair called for reports of committees as follows:

Finance Committee, Charles S. Cushing, *Chairman*.—Mr. Cushing made a verbal report, showing the general financial condition of the Society to be prosperous. He stated that he, together with A. H. Markwart and Dr. James D. Maddrill, as an Auditing Committee, had examined the books and accounts of the Treasurer and found them correct.

Publication Committee, H. D. Curtis, *Chairman*.—Dr. Curtis reported a satisfactory condition of things in the workings of his committee and stated that the reduction of the membership of the committee to two, and its concentration in one place, was greatly facilitating the work and enabling them to get the *Publications* out on time.

Library Committee, D. S. Richardson, *Chairman*.—Mr. Richardson reported the addition of eight volumes to the library during the past year, in addition to numerous unbound papers and periodicals received from exchanges and corresponding astronomical institutions.

Comet-Medal Committee, W. W. Campbell, *Chairman*.—In the absence of Dr. Campbell, President Curtis read the report of this committee as printed on pages 268 and 269 of the December, 1912, *Publications*. There were three awards during the year, i. e. to Messrs. Walter F. Gale, of Sydney; A. Borrelly, of Marseille, and A. Schaumasse, of Nice.

On motion of Dr. A. O. Leuschner, seconded by Mr. Charles S. Burckhalter, the foregoing reports were received and approved.

The next business in order was the election of a Board of Directors and a Committee on Publication for the ensuing year.

The Nominating Committee, consisting of J. D. Galloway, Chairman, Messrs. Allen H. Babcock and B. A. Baird, presented a report, making the following nominations:—

For Members of the Board of Directors—R. G. Aitken, G. E. Hale, A. G. McAdie, F. V. Cornish, R. T. Crawford, J. Costa, W. H. Crocker, D. S. Richardson, C. S. Cushing, S. D. Townley, and A. H. Markwart.

For Publication Committee—R. G. Aitken and H. D. Curtis.

On motion of Leuschner, seconded by Morse, the nominations were declared closed. The chair appointed Messrs. Ziel and Paddock as tellers and announced that, in compliance with the provisions of the By-Laws, the polls would remain open until 9:00 p. m.

The address of the evening by the retiring President, Dr. H. D. Curtis, was now given.

Dr. Curtis' subject, which was "Our Stellar Universe," beautifully illustrated with lantern slides, in addition to proving most interesting and instructive to astronomers and laymen present, was seized upon by the speaker as an opportunity to introduce the fine services rendered to astronomy by the Bruce Medalist of the present year, Dr. J. C. Kapteyn, director of the Astronomical Laboratory of Groningen, Holland. The eulogy paid by the lecturer to that distinguished scientist was generous and fitting.

At the conclusion of the lecture, the tellers counted the ballots and announced that the officials, as above nominated, were unanimously elected.

Adjourned.

D. S. Richardson,
Secretary.

Report of the Treasurer of the Astronomical Society of the Pacific for the Last Ten Months of the Fiscal Year Ending January 25, 1913.*

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* The By-Laws, as amended at the meeting of March 30, 1912, changed the date of the annual meeting from March to January, effecting a corresponding change in the fiscal year of the Society.

GENERAL STATEMENT.

Liabilities.

To the William Alvord Fund	$ 5,000 00
" Alexander Montgomery Library Fund	3,772 80
Donohoe Comet-Medal Fund	853 53
Bruce Medal Fund	2,934 20
Life Membership Fund	1,974 36
" John Dolbeer Fund	5,000 00
" General Fund	682 74
Total	$20,217 63

Assets.

Bonds in custody of Mercantile Trust Co.	$14,418 02
Cash in Humboldt Savings Bank (Alvord Fund)	305 74
" Savings Union Bank (Alvord Fund)	454 70
" Savings Union Bank (Comet Fund)	853 53
" Security Savings Bank (Library Fund)	613 78
" Mutual Savings Bank (Bruce Medal Fund)	944 48
" German Savings and Loan Society (Life Membership Fund)	974 36
" Union Trust Co. (Dolbeer Fund)	970 28
" Donohoe-Kelly Banking Co. (General Fund)	682 74
Total	$20,217 63

STATEMENT BY FUND.

Wiliam Alvord Fund.

Dr.	
To Balance March 30, 1912	$ 5,000 00
Bond Interests for year	200 00
Bank Interests	30 71
	$ 5,230 71
Cr.	
By Transfers to General Fund	230 71
Balance January 25, 1913	$ 5,000 00

Alexander Montgomery Library Fund.

Dr.	
To Balance March 30, 1912	$ 3,777 82
Bond Interests for year	150 00
Bank Interests	24 98
	$ 3,952 80
Cr.	
By Transfers to General Fund	180 00
Balance January 25, 1913	$ 3,772 80

Donohoe Comet-Medal Fund.

Dr.	
To Balance March 30, 1912	$ 820 41
Bank Interests for year	33 12
Balance January 25, 1913	$ 853 53

Bruce Medal Fund.

Dr.	
To Balance March 30, 1912	$ 2,945 84
Bond Interests for year	50 00
Bank Interests	38 36
	$ 3,034 20
Cr.	
By Check on Anglo & London-Paris National Bank—Medal for 1913	100 00
Balance January 25, 1913	$ 2,934 20

LIFE MEMBERSHIP FUND.

Dr.		
To Balance March 30, 1912		$ 1,974 36
Bond Interests for year		40 00
Bank Interests		39 33
		$ 2,053 69
Cr.		
By Transfers to General Fund		79 33
Balance January 25, 1913		$ 1,974 36

JOHN DOLBEER FUND.

Dr		
To Balance March 30, 1912		$ 5,000 00
Bond Interests for year		140 00
Bank Interests		36 70
		$ 5,176 70
Cr.		
By Transfers to General Fund		176 70
Balance January 25, 1913		$ 5,000 00

GENERAL FUND.

Dr.		
To Balance March 30, 1912		$ 847 10
William Alvord Fund		230 71
Library Fund		180 00
Life Membership Fund		79 33
John Dolbeer Fund		176 70
Bruce Medal Fund		100 00
Dues		219 75
Sale of *Publications*		11 00
Total		$ 1,844 59
Cr.		
By Blair-Murdock Co., for printing	$ 573 50	
Lantern Service	10 00	
Engraving Comet Medals	4 91	
Postages	17 63	
Bruce Medal Fund	100 00	
Rent	202 50	
Salary of Secretary-Treasurer	200 00	
Membership Dues Pacific Association of S. S.	5 00	
Taxes	14 66	
Insurance on Library	7 50	
R. G. Aitken, for Janitor at Lick	5 00	
Notary Fees and Expressage	1 05	
Safe Deposit Box	4 00	
Mercantile Trust Co.—Care of Bonds	14 00	
Cards for Library Index	2 10	1,161 85
Balance January 25, 1913		$ 682 74

The following is a detailed description of the fourteen bonds owned by the Astronomical Society of the Pacific and held in deposit by The Mercantile Trust Company of San Francisco, at 464 California Street.

These securities are all of the face denomination of $1,000, and the values given represent their original cost to the Society:—

Life Membership Fund.	
One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937; interest payable in January and July	$ 1,000 00
Alexander Montgomery Library Fund.	
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932; interest payable in January and July	1,040 00
One Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bond, No. 641. Principal due October, 1929; interest payable April and October	1,084 02
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665, Principal due January, 1915; interest payable January and July..	1,035 00
Bruce Medal Fund.	
One Bay Counties' Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1636. Principal due September, 1930; interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922; interest payable in March and September	977 22
John Dolbeer Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937; interest payable in January and July	1,000 00
One Oakland Transit Consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932; interest payable January and July	1,040 00
One Bay Counties Power Company's 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1637. Principal due September, 1930; interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922; interest payable March and September	977 22
William Alvord Fund.	
Two Sunset Telephone and Telegraph Company's consolidated mortgage 5 per cent Gold Bonds, Nos. 656 and 657. Principal due October, 1929; interest payable in April and October	2,168 06
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915; interest payable in January and July	2,071 50
Total, 14 bonds, value	$14,418 02

Outstanding bills against the Society, none.

Membership dues remain unpaid as follows:—

For the year 1910	$ 35 00
" " " 1911	80 00
" " " 1912	170 00
Total	$ 285 00

The present membership of the Society is as follows:—

Life Members	58
Active Members	123
Institutional Members	34
Total	215
Exchanges	28
Corresponding Institutions	98
New Members elected during the year	8
Resignations	6
Deaths of Members reported	3

Respectfully submitted,
D. S. RICHARDSON,
Treasurer.

The foregoing account has been examined and found correct.

CHARLES S. CUSHING,
A. H. MARKWART,
J. D. MADDRILL,
Auditing Committee.

MEETING OF THE NEW BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC ON JANUARY 25, 1913, IN THE ROOMS OF THE SOCIETY, 748 PHELAN BUILDING, SAN FRANCISCO, CALIFORNIA, AT 9:30 P. M.

Present Directors R. T. CRAWFORD, CHARLES S. CUSHING, A. H. MARKWART, F. V. CORNISH, J. COSTA, and D. S. RICHARDSON.

On motion of CUSHING, seconded by CRAWFORD, the name of A. G. MCADIE was put in nomination for President for the ensuing year, and that gentleman was unanimously elected.

The organization of the new Board of Directors was then completed by the unanimous election of the following officers to serve for the ensuing year:—

For First Vice-President—R. G. AITKEN.
For Second Vice-President—R. T. CRAWFORD.
For Third Vice-President—J. COSTA.
For Secretary-Treasurer—D. S. RICHARDSON.
For Secretary on Mount Hamilton—R. G. AITKEN.
For Library Committee—Messrs. RICHARDSON, COSTA and MARKWART.

On motion, duly seconded and carried, it was resolved that the time for holding the next meeting of the Society, which nominally falls in March, should be left to the discretion of the President and Secretary in order that it might be adjusted, if thought desirable, to the April meeting, in Berkeley, of the Pacific Association of Scientific Societies.

Adjourned. D. S. RICHARDSON,
Secretary.

OFFICERS OF THE SOCIETY

Mr. Alex. G. McAdie	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. R. T. Crawford	*Second Vice-President*
Mr. J. Costa	*Third Vice-President*
Mr. D. S. Richardson	*Secretary-Treasurer*
Mr. R. G. Aitken	*Secretary on Mount Hamilton*

Board of Directors—Messrs. Alex. G. McAdie, R. G. Aitken, R. T. Crawford, J. Costa, D. S. Richardson, W. H. Crocker, S. D. Townley, G. E. Hale, F. V. Cornish, C. S. Cushing, A. H. Markwart.

Finance Committee—Messrs. C. S. Cushing, W. H. Crocker, A. H. Markwart.

Publication Committee—Messrs. R. G. Aitken, H. D. Curtis.

Library Committee—Messrs. D. S. Richardson, J. Costa, A. H. Markwart.

Comet-Medal Committee—Messrs. W. W. Campbell, S. D. Townley, H. D. Curtis.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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THE MAGNITUDE SCALE OF THE DURCHMUSTERUNG.

By R. H. Tucker.

At the August, 1912, meeting of the Astronomical and Astrophysical Society, Professor E. C. Pickering presented a paper which included a comparison of the photometric magnitudes, published in volumes 70 and 74 of the *Harvard Annals*, with the magnitudes of the Bonn, Córdoba, and Cape volumes of the *Durchmusterung*. The brief abstract of this comparison, printed in *Science*, No. 940, of January 3, 1913, gives only the results at the fainter end of the D. M. scale, and some indications of variation in the scale of the southern portions.

There are four separate parts in the scheme of the *Durchmusterung*, thus referred to; and the northern and southern portions, observed at Bonn, should be treated individually. The northern sky was covered by Argelander, and the limit of brightness to which the scheme was designed to be complete was set at ninth magnitude. The observations were made with a three-inch telescope, with dark field, and the faintest stars included were called 9½, though this limiting grade was certainly an elastic one, and many stars fainter than 9.5, on his scale, were observed.

The elastic nature of the lowest grade is of importance to observers, when selecting stars from the northern scheme. Stars recorded as 9.1 to 9.4, for instance, have been determined by several observations, in which some of the estimates were brighter than 9½, and the mean value for any star will probably be found to represent its brightness on the Argelander scale. But for 9.5 this relation no longer holds, and a star of that grade may be very much fainter, down to the faintest observed. The faintest star visible should have been below eleventh magnitude, and it is nearly certain that some tenth-magnitude stars are included.

The next adjoining portion of the *Durchmusterung* extends to 23° south, and was observed by SCHÖNFELD, who had been associated with ARGELANDER in the observation of the northern sky. While his previous experience should have assured the extension of the same scale of magnitudes to the southern sky, the circumstances were somewhat changed. He observed with a six-inch telescope, the limit of visibility of which, with a dark field, should have been thirteenth magnitude. But, in order to insure greater precision in the places of the stars, he used a slightly illuminated field, and his visible limit of brightness was accordingly changed. His design, also, was to include all stars to the magnitude 9½, and he observed and recorded his grades down to tenth magnitude. His catalogue includes an average of eighteen stars to the square degree, while the catalogue of the northern sky includes fifteen to the square degree.

The Córdoba *Durchmusterung,* which began at —22°, thus overlapping one degree on SCHÖNFELD, was also planned to extend the Argelander scale of magnitudes to the southern sky. Our preliminary practice was done on portions of the northern zones, with careful comparison and discussion of results, usually made on the day following the observations of a night. There is probably no class of observing that demands more thorough special training. The aims of the *Durchmusterung* may be described as the complete inclusion of all stars to a definite limit of brightness, the ranking of all the stars observed on a graded scale of brightness, and the substantial precision of the places of the stars within the limits of error allowed for this class of work. These limits are, of course, greater than those of instrumental measures, but should be within those necessary for the certain identification of the stars. The importance of the several aims takes precedence in this order.

Atmospheric absorption plays a part in diminishing the apparent brightness of the stars, noticeable only at low altitudes. Its effect upon the stars observed by ARGELANDER would not have much exceeded a tenth of a unit, down to the equator. The effect on the comparisons made at Córdoba, with the northern zones, would be still less. On the other hand, for the lowest altitudes at which SCHÖNFELD observed, the absorption would amount to 0.6 magnitude. Of course, the observer, for very low altitudes, can make allowance for the effect, if it may be sensible. The Córdoba observations were all made at small-hour angles, and, for the work hitherto published, the amount of absorption has probably been negligible.

The illumination of the field of view will cut down the limit of visibility and might affect the scale, but should not sensibly change the relative sequence in the grades of magnitude. No observations were made at Córdoba when any sky illumination from the Moon, though below the horizon, could be detected. The brighter background of the sky in the Milky Way can be conceived as affecting the scale, in the manner of artificial illumination, so that visual D. M. estimates might be too faint in that region.

The plan at Córdoba was to include all stars of the tenth magnitude, and, in order to be sure of accomplishing this end, many stars fainter than that grade were observed, consciously so very often. The published grade 10 is then an elastic grade, as was ARGELANDER's 9.5, and while the scale up to 9.9, inclusive, represents the mean of several estimates in each case, and is a definite sequence of grades, the 10 may represent stars decidedly fainter than the position assigned to them in the scale. The observations were made with a five-inch telescope, for which the visible range would not extend much below twelfth magnitude. For the first twenty degrees, the observations were made with a dark field; and a test made by myself in the search for a twelfth-magnitude asteroid, upon the faintest stars seen, identified the missing object. No effort was ordinarily made to reach the faintest stars visible, and it is probable that no stars fainter than eleventh magnitude are included, though that limit may have been reached.

Internal evidence of the character of the scale may be found in the distribution of grades by the count of stars in the catalogue, and such evidence was published in my note in the *Astrophysical Journal* for May, 1898. In that note it was shown that the Córdoba *Durchmusterung* includes a total equivalent to that of all the stars to the magnitude 10¼, on its own scale. The grade 10¼ would not be complete, on this basis, but enough stars fainter than that grade would be included to bring the total number up to the summation of all to 10¼ inclusive.

After my departure from Córdoba, when the third ten-degree section had been about one fifth completed, the observations were made with a faintly illuminated field. While this may have produced an effective increase in the precision of the places, it is certain to have cut down the limit of visibility, and it is not likely that anything as faint as eleventh magnitude would have been observed, in the continuation, mainly from 42° south. This change of observing practice is important, in view of the difference in scale found for the two portions by Professor PICKERING, which will be made the subject of further illustration later.

The Córdoba *Durchmusterung* has been published for the thirty degrees, 22 to 52, and the next following ten degrees was observed by Dr. THOME, and was practically all reduced before his death. The published part contains fifty-seven stars to the square degree.[1]

The fourth part of the *Durchmusterung,* done at the Cape of Good Hope, covers the southern sky from 19° south by photographic methods, thus including parts of the areas covered by SCHÖNFELD and at Córdoba. The places, derived from the measures of the plates, are much more precise than those of the visual *Durchmusterung.* The published magnitudes vary greatly in their limits for various parts of the sky, ranging from 9.6 to eleventh magnitude, and below. From my own discussion and comparison of its scale, as well as from estimates of others, the photographic list may be credited as pretty certainly including all stars to the magnitude 9.0 of the visual scale, excepting very red stars. Below that point it includes various numbers of stars in different portions; nowhere, however, certainly complete to a fainter grade than ninth.

The scale of magnitudes is based upon that of the Córdoba

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[1] The proportion of Córdoba to ARGELANDER, 57 : 15 = 3.8, is closely that called for by the theoretical extension of the summation of the stars to one extra unit of the visual scale.

Zone Catalogue, the observations of which were all made by Dr. B. A. Gould. The measurements of the photographic images were compared with this scale, and curves were derived to represent all parts. This would only carry the magnitudes down to about 9½; for stars estimated as fainter than that grade, in the *Zone Catalogue*, were pretty certainly observed under unfavorable conditions, and have been found, in the comparisons with D. M., to be at least as bright as the average 9½ of the same scale. In obtaining the constants of reduction for the D. M. places, I used every star from the *Zone Catalogue* that falls within the first twenty degrees. The zone estimates of magnitude were generally fainter than those of the D. M., the average difference amounting to one quarter at ninth magnitude. In the comparison of the photographic scale with the visual, in the note in the *Astrophysical Journal* referred to above, the estimates of the photographic D. M. were found to be in general about a quarter of a magnitude fainter than the visual outside the Milky Way; and nearly a quarter brighter in some portions of the Milky Way. This apparent change in scale corresponds with the statement of Kapteyn that, as compared with the visual D. M., the fainter stars of the *Zone Catalogue* have been estimated half a magnitude brighter in the Milky Way than at the poles of that belt.

These points are necessary to be considered in the relation of the various scales, all of which are really extensions beyond the basis of comparison, which, for the visual scale, is the well-established and generally accepted magnitude scale of Argelander. In volume 23, *Harvard Annals*, page 183, the photometric scale is stated to be a quarter of a magnitude brighter than the visual D. M. at ninth magnitude, with irregular variations in the difference for the brighter stars.

The photometric scale, while it is made up from measures of comparative brightness, has been finally reduced to the visual standard, as nearly as possible. For the fainter stars, the scale is, in general, an extension beyond the base of comparison, as in the visual estimates. The Harvard photometric work has been mainly done with three separate instruments and has been made up of many sections. The first photometer had a telescope of 1½ inches aperture, and *Polaris* was employed for a comparison star. This was succeeded by a four-inch telescope, and λ *Ursæ Minor* 6.6 was used for faint stars, as well as *Polaris*. For the southern sky σ *Octantis*, magnitude 5.5, was used as a comparison star; and throughout the photometric work many circumpolar stars were referred to as standards. In the latest photometer, largely used in the southern hemisphere, a 12-inch telescope was employed, and an artificial star of about the equivalent of sixth magnitude was used for comparisons. The results of this last photometer appear to have been reduced to the scale of the 4-inch, by comparisons of the measures common to both instruments. Large variations of wedge values have been included in the reduction of the photometric measures. Thus we find in a late publication, *Harvard Annals*, **72**, page 82, that the wedge constant varied 1.37 magnitude through a range of thirty-two divisions, following the first twenty-eight divisions. Beyond the part of the scale where sufficient comparisons can be made with visual estimates, the photometric measures must have a considerable amount of uncertainty.

Thus far the separate scales have been given in outline. The brief abstract in *Science*, referred to in the first paragraph above, has led me to supplement its figures by a more detailed comparison of the scales, taken from the same sources. Sufficient comparisons have been taken from the two series at Bonn and from — 24° Córdoba to give the general trend of the respective differences, the published results in *Harvard Annals*, **70**, having furnished the figures in convenient form.

The results of the comparisons are tabulated below, as corrections to the visual scales, given by the photometric scale. The first column gives the magnitude from the visual D. M. The corrections to ARGELANDER, SCHÖNFELD, and Córdoba follow in order, tabulated for each tenth magnitude, and combined for approximate quarter magnitudes. The plus signs indicate that the visual estimates are brighter than the photometric. The lowest grade of ARGELANDER and that of Córdoba are bracketed, because they represent elastic estimates, as already explained. The lowest grade of SCHÖNFELD appears to correspond to the rest of his scale above.

[illegible] the different visual scales with each other, [illegible] this table, it must first be assumed that [illegible] the photometric work, made with vari- [illegible] are really homogeneous, and represent a uni- [illegible] the parts of the sky covered. The vast [illegible] thorough investigation that has been [illegible] Harvard measures represented fully in [illegible] seems to be sufficient assur- [illegible] has been done for this purpose. It is [illegible] the approximate relations of the several [illegible] in the second part of the table below. [illegible] system is in good accord with the [illegible] the faint stars up to ninth magnitude [illegible] brighter at that point, and a decided [illegible] at the closing grade 9.5 of the northern [illegible]

[illegible] brighter than the photometric scale [illegible] amounting to one and a quarter [illegible] limit.

[illegible] are brighter than the photometric by a [illegible] to ninth, and the difference increases [illegible] at tenth magnitude, the published [illegible] given above.

[illegible] relations of the visual scales are [illegible] part of the table. [illegible] are [illegible] brighter than [illegible]

[illegible]

[illegible]

Mag.	Arg. N.D.M.		Sch. S.D.M.		Cor. D.M. —24°		Δ Visual D.M.		
							C — A	C — S	S — A
8.5	—0.1	—0.1	+0.1	+0.1	+0.5	+0.5	+0.6	+0.4	+0.2
8.6	0.0		+0.4		+0.5				
8.7	0.0		+0.2		+0.5				
8.8	+0.1	0.0	+0.3	+0.3	+0.5	+0.5	+0.5	+0.2	+0.3
8.9	0.0		+0.3		+0.6				
9.0	+0.1	+0.1	+0.4	+0.4	+0.6	+0.6	+0.5	+0.2	+0.3
9.1	+0.3		+0.6		+0.8				
9.2	+0.3	+0.4	+0.7	+0.7	+0.8	+0.8	+0.4	+0.1	+0.3
9.3	+0.5		+0.8		+0.8				
9.4	+0.6		+1.0		+0.9				
9.5	+1.4	[+1.4]	+1.1	+1.1	+1.1	+1.1	[—0.3]	0.0	[—0.3]
9.6			+1.1		+1.2				
9.7			+1.2		+1.1				
9.8			+1.4	+1.4	+1.6	+1.4		0.0	
9.9			+1.6		+1.4				
10			+1.3	+1.3	+1.8	[+1.8]		[+0.5]	
Average Δ.							+½	+¼	+¼

This table illustrates the relation between the photometric and visual scales, for the faint stars, but it gives no indication of which corresponds to the intrinsic brightness of the stars included. The photometric scale is evidently much the longer, for the range of brightness represented; that is, photometric estimates have a range of at least three units of magnitude, where the visual have two. Photometric measures of the faintest stars of SCHÖNFELD go to twelfth magnitude and beyond, and of the faintest of Córdoba to thirteenth and beyond. It is not likely that stars so faint could have been seen, during the observations of either visual scheme, and the lowest estimates of the photometric are unquestionably too faint. The photometric estimates of ARGELANDER'S 9.5 go down to twelfth magnitude and below, fainter stars than would have been visible in his telescope. His 9.5 are apparently nearly all estimated on the photometric scale as fainter than 10.

The figures of the table may be taken as a general confirmation of the brief statement of Professor PICKERING in the note referred to at the beginning of this. Combining the results of the two sections of Bonn, those of ARGELANDER and of SCHÖNFELD, the photometric estimates are about one unit of magnitude fainter than the visual at 9½, but SCHÖNFELD'S estimates are apparently one quarter brighter than ARGEL-

ANDER's at that point of the scale. The photometric estimates are one and a half units fainter than Córdoba, at the real 10 of the scale of the latter, which is in close agreement with SCHÖNFELD from nine to ten. As the Córdoba 10 includes many stars really estimated as fainter than true 10 on its own scale, the mean of the photometric estimates for that grade covers a wide range, over two units of the photometric scale. During part of the Córdoba work it was the custom to record stars fainter than 10 by the letter *a*, but the practice was not continued long. In combining individual estimates, this grade *a* was treated as 10 in the early work. But in the later volume, 42° to 52° south declination, this grade was apparently called eleventh magnitude, and there are a few stars printed as 10.5 in this later section. The change in the Córdoba scale below 42° may be explained by the change in observing practice, already noted in the preceding description. Further discussion of the two areas, which I expect to complete soon, will make this difference evident.

Some light upon the respective scales can be sought in the determination of the so-called absolute scale of magnitude, based upon counts of the stars; and this point I hope to take up later, with material already partially reduced.

The abstract of the note of Professor PICKERING gives the average deviation between the photometric and the photographic magnitudes, after applying corrections for the class of spectrum to the latter. These deviations were found to be ± 0.2 magnitude, after having been reduced one half by grouping stars on the same plate. In my comparison between the Córdoba magnitudes of the first ten degrees and those of the photographic *Durchmusterung*, the average deviation was found to be ± 0.3 magnitude, which apparently represents about the same degree of precision. In the present comparison, taking the average deviation from the photometric mean of the groups for each tenth of the scale, this is found to be ± 0.3 magnitude for the ARGELANDER from 8.0 to 9.4. For SCHÖNFELD it is ± 0.3 magnitude on the average, slightly larger for the faintest stars. For Córdoba it is ± 0.3 magnitude to 9.9 and ± 0.5 for the elastic grade 10. The respective scales appear to be each consistent, from the consideration of all these figures.

A final word of warning may be written for the benefit of those observers who desire precise places for comparison stars, for comets and asteroids. It is often assumed that the place of any D. M. star can be later measured with meridian circles. The telescopes of modern instruments are generally of smaller size than some of the older types. Instead of eight and nine inches, the latter theoretically capable of showing fourteenth magnitude in a perfectly dark field, the usual size is about six inches, theoretically capable of thirteenth magnitude under the same conditions. This is apparently an effective reduction of a whole magnitude.

With our instrument, of 6.4 inches aperture, I believe I can always count upon a satisfactory observation of a star of 9½, with sufficient illumination in the field. A star probably of tenth magnitude can be observed, with difficulty, under the best atmospheric conditions. With the 8-inch of the Dudley Observatory, used recently at San Luis, we often observed stars which I estimate as no brighter than tenth magnitude. In selecting stars from the northern D. M., they should be confined to the grade 9.4 and brighter, if possible. There will always be some uncertainty in securing observations of ARGELANDER'S 9.5.[1] From SCHÖNFELD'S D. M. the selection should be confined to stars of 9¼ or brighter, if a star of 9½ visual scale be taken as the usual limit of precise observation with modern meridian circles. In selecting from the Córdoba D. M., the corresponding limit should also be 9¼, the estimates for the faint stars being pretty certainly one-quarter magnitude too bright. I have recently found it not possible to observe a 9.8, and a 9.5 from SCHÖNFELD, though I observed one of 9.6. I have taken stars of 9.5 ARGELANDER, and recently one star not in his catalogue. These observations were made during a period when extremely red sky at sunset indicated a large amount of dust, probably volcanic, in the atmosphere, and a possible consequent diminution of transparency.

The meridian-circle observers at Córdoba usually found any of our D. M. stars estimated as fainter than 9.0 to be difficult.

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[1] The limit set for the *Gesellschaft* zones was the D. M. 9.0, while the inclusion of previously observed fainter stars was also recommended.

That instrument, the original meridian circle mounted by Dr. GOULD, has an aperture of 4.9 inches only, and a twelfth magnitude star should be visible with its use in a dark field. The illumination in the field of a meridian circle cannot usually be as delicately adapted to the sight as in micrometer work with an equatorial. Tenth-magnitude stars can be observed, but the difficulties are sensible, and the uncertainty of the scale at the lower end of the visual *Durchmusterung* must be considered.

Astronomical photographs can go as far as desired, with sufficiently long exposures. But the unequal distribution of the faintest grades, published in the Cape *Durchmusterung*, raises the question of the actual brightness of the corresponding stars. Below ninth magnitude there are estimates extending over a considerable range, but so few proportionately of each grade that it would be hard to say what low grade is completely included. The colors of the faint stars are usually considered to show but little variety to account for this condition.

March 14, 1913.

THE INFLUENCE OF GRAVITATION ON LIGHT.

By HEBER D. CURTIS.

In *Annalen der Physik*, 35, 898, 1911, Dr. A. EINSTEIN postulates the hypothesis that a ray of light will suffer deflection, or quasi-refraction, when passing through a powerful field of gravitation. This hypothesis is a result of the theory of relativity,[1] but from what we know of the behavior of light when passing through matter or a strong magnetic field, it is perhaps not inherently impossible that some such action should exist independently of the requirements of the theory of relativity. Physicists, it may be said parenthetically, are to-day divided into two warring camps on the subject of the theory of relativity, and whether it will ever become generally accepted is an open question, particularly as EINSTEIN has recently been forced to make certain rather radical alterations in the theory as originally stated by him. EINSTEIN puts forward the theory of the bending of light rays by gravitation with some reservation, but closes his paper with the words: "It is greatly to be desired that astronomers should undertake this investigation, although the foregoing reasoning may prove to be insufficiently founded or even entirely illusory. For, aside from any theory, the question must be considered, whether with our present resources an influence of the gravitation field on the propagation of light can be established."

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[1] *Publications, A. S. P.*, 23, 219, 1911.

EINSTEIN points out that we have a way to test this hypothesis by investigating the positions of stars seen near the Sun at the time of total solar eclipse. His formula (true to the first order only) for the deviation suffered by a ray of light passing through a gravitational field is,—

$$\alpha = \frac{2kM}{c^2D},$$

where k is the gravitation constant; M the mass of the attracting body; c the velocity of light, and D the distance from the path of the ray to the center of attraction. Adopting 6.14×10^{27} grams as the mass of the Earth (mean density 5.67); $g = 981^{\mathrm{cm}}$; Sun's mass : Earth's mass = 330,000 : 1; and $695{,}500^{\mathrm{km}}$ as the radius of the Sun, a ray of light passing close to the limb of the Sun should, in accordance with the formula given above, suffer a deflection toward the Sun of about $0''.86$, the apparent angular distance of the star from the Sun's center being *increased* by this amount. The effect varies inversely as the distance of the ray-path from the center of the Sun; if the star's distance, D', from the Sun's center is expressed in minutes of arc, the effect will be given by, $\alpha'' = 13.8/D'$.

The *doubled* effect, for pairs of stars situated on opposite sides of the Sun, will be as follows, the distances being expressed, for convenience, in minutes of arc from the *limb* of the Sun:—

Distances from Sun's Limb.	2α
5′	1″.32
10	1 .06
20	0 .76
30	0 .60
40	0 .50
50	0 .42
60	0 .36

These doubled effects are small, but not beyond the reach of measurement on plates taken with instruments of fairly long focus.

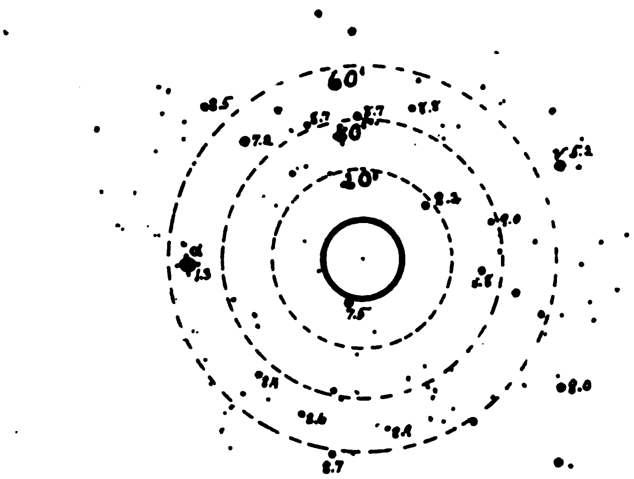
Probably the only observational material at present available to test the truth or falsity of this hypothesis is that afforded by the series of plates taken in the searches for intramercurial planets at the Lick Observatory-Crocker Eclipse Stations in 1901, 1905, and 1908. These plates were taken with lenses of three inches aperture and eleven feet four inches focal length, and copies on glass of certain of these negatives have been sent to Dr. FREUNDLICH, of Berlin, for measurement in connection with this problem. Unfortunately, it seemed evident in advance that no results of value could be secured from these plates, and Dr. FREUNDLICH has since abandoned the attempt to measure any deflection effect from them. These intramercurial search plates were taken for an entirely different purpose; very large plates were used, and the image of the eclipsed Sun is on the very edge of these large plates, with the result that the distortion not only cuts out the fainter star images, but leaves any visible images near the Sun fan-shaped, so that it is impossible to measure these with any accuracy. Moreover, these plates were taken with the driving clock rated to solar rather than sidereal time; this rating would cause the star images to show a trail of about seven seconds of arc in an exposure of three minutes. For the purposes of this investigation the image of the Sun should be central on the plate, the mounting as rigid as possible, and the driving clock rated on stars, instead of on the Sun. Under the best conditions exposures of two to three minutes should then show sharp images of many stars as faint as magnitude 9.5.

I have carefully examined the intramercurial plates taken at Flint Island in 1908, in the effort to determine the limiting factors for measureable star images in terms of magnitude and distance from the Sun's limb. The distance of the image of the Sun from the center of the plate, mentioned above, and the fact that these negatives show two images of each star, makes a definite statement difficult, but I would estimate, somewhat at a venture, that the limit of visibility of star images with Sun central on plate, images sharp, sky clear, and exposures two minutes in length, would be,—

Magnitude 7.5, visible to 15′ from Sun's limb.
" 8.5, " " 25′ " " "

These limits might be somewhat smaller for images favorably situated outside of streamers or stronger regions of the corona.

For the Russian eclipse of August 20-21, 1914, the maximum duration of which will be two minutes and fourteen seconds, the conditions for testing this problem will be about as represented in the accompanying cut. The magnitudes of only the brighter B. D. stars are given, and the dotted circles are drawn at distances of 20, 40, and 60 minutes of arc from the Sun's limb. *Regulus* and *ν Leonis* are fairly favorably placed; these two stars should show an apparent increase of about 0″.35 in distance, but the great brilliancy of *Regulus* would operate to make the measures on its image subject to large errors. There is quite a favorable arrangement of fainter stars symmetrically placed about the Sun. Most of these should show distinctly



STARS NEAR SUN.
Eclipse of August 20-21, 1914.

if the following were perfect, and *Regulus* would make an excellent guiding star for this purpose, though it would doubtless be better to install an electrical clock-control, and omit all attempts at guiding by hand. At least four lenses should be used, with chart plates of this region made in advance at approximately the altitude which this region would have at the time of the eclipse. Star plates should also be taken on one or two nights immediately preceding the eclipse as a control on the scale value of the plates.

From EINSTEIN's formula the effect for *Jupiter* would be only about one one-hundredth of that caused by the Sun; in occultations by the Moon the effect would be entirely insensible, amounting to only one one-hundred-thousandth of a second of arc.

A CORRECTION.

In the February number of these *Publications* (page 52) a note was printed to the effect that the great disk of glass for the 100-inch reflector for Mount Wilson had finally been rejected as useless for the purpose. This note was based upon a similar one which appeared in *Popular Astronomy.*

It is a great pleasure to be able to correct this statement. A personal letter from Mr. WALTER S. ADAMS says that, while "the first tests showed quite an unsatisfactory figure," in that the figure of the glass did not rotate with the disk when it was rotated, indicating "an apparent bending of the glass unequally along two diameters at right angles to one another," later experiments have located the source of the difficulty in the edge-support. The "last tests proved conclusively," Mr. ADAMS continues, "that when the glass is properly supported the figure rotates perfectly with the disk. In view of these tests we have already accepted the disk and made payment for it, and are going forward with our plans on the dome and mounting of the telescope."

This will be good news to astronomers the world over, and they will all unite with us in hearty congratulations to the Solar Observatory staff upon this successful outcome.

THE COMMITTEE ON PUBLICATION.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1913.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon ...	May 6,	$12^h 24^m$	A.M.	New Moon ...	June 4,	$11^h 57^m$	A.M.
First Quarter..	" 13,	3 45	A.M.	First Quarter..	" 11,	8 37	A.M.
Full Moon ...	" 19,	11 18	P.M.	Full Moon ...	" 18,	9 54	A.M.
Last Quarter..	" 27,	4 4	P.M.	Last Quarter..	" 26,	9 41	A.M.

The Sun reaches the summer solstice and summer begins on June 21st, about 5 P. M., Pacific time.

Mercury at the beginning of June is a morning star, rising rather less than an hour before sunrise. It is more than 20° east of the Sun, but it is also 12° south of that body, and consequently does not rise early enough for naked-eye visibility. It passed greatest west elongation on April 24th, and on June 1st it reaches superior conjunction, becoming an evening star. Its distance from the Sun increases rapidly, and before the middle of the month it remains above the horizon an hour or more after sunset. This interval increases to a little more than an hour and one-half by the end of the month, and the planet will reach its greatest east elongation early in July. It may be seen during the latter half of June on any clear evening low down in the western sky shortly after sunset very nearly in the position occupied by the Sun an hour and a half earlier.

Venus passed inferior conjunction with the Sun and became a morning star on April 24th. Its motion away from the Sun is quite rapid, and by May 1st it rises about three-quarters of an hour before sunrise. The superior brightness of *Venus* permits it to be visible to the naked eye in this position, although probably no other planet could be seen in a similar position with respect to the Sun and the horizon. The telescopic appearance of *Venus* is now very beautiful, that of a new moon only a few days old. This same appearance was presented a few days before the time of inferior conjunction. By the end of May the planet will rise nearly two hours before sunrise and somewhat more than two hours at the end of June. This interval is not nearly as great as the corresponding interval between the setting of the Sun and that of the planet while the planet was an evening star before conjunction, as *Venus* is now in a part of its orbit considerably south of the Sun. *Venus* reaches its greatest actual distance from the Sun and is in aphelion on June 24th.

Mars rises shortly after 3 A. M. on May 1st and shortly after 1 A. M. on June 30th. During this two months' period it moves about 32° eastward and 12° northward through the constellation *Pisces*, passing about 1° 20′ south of the vernal equinox on May 7th. It passes its perihelion on May 18th. Its brightness on May 1st is about 15 per cent of its brightness at the next opposition in January, 1914, and this number increases to about 20 per cent by the end of June, its actual distance diminishing from 175 to 151 millions of miles. Its brightness at this time is greater than it is ordinarily when the planet is at its present apparent distance from the Sun, as it is twenty or more millions of miles nearer the Earth than it would be if aphelion passage came during May instead of perihelion.

Jupiter is moving around to a good position for evening observation, rising at about midnight on May 1st and before 8 P. M. on June 30th. It is in the constellation *Sagittarius* and up to May 7th moves a little eastward. It then begins its westward or retrograde motion, and by the end of June has moved not quite 5°. It will then be about 5° north of the easternmost star of "the Milk Dipper."

Saturn sets before 9 P. M., less than two hours after sunset, on June 1st, and its distance from the Sun diminishes rapidly, so that by the middle of the month it sets less than an hour after sunset and is therefore practically beyond the limit of naked-eye visibility. It passes conjunction with the Sun and becomes a morning star on May 29th. At the end of June it will rise shortly before 3 A. M., less than two hours before sunrise.

Uranus on May 1st rises at about 1 A. M. and on June 30th at about 9 P. M. It is therefore moving around toward a condition for naked-eye visibility. On account of its faintness (it is less than a sixth-magnitude star in brightness) it can scarcely be seen at a height of less than 15° above the horizon. During May it is nearly stationary and by the end of June has moved a little less than 1° westward. It is in the constellation *Capricorn* and not near any bright star. It is about 1° east and a little south of the fifth-magnitude star *υ Capricorni.*

Neptune is still in the western evening sky, setting at about midnight on May 1st and shortly after 8 P. M. on June 30th. It moves about 2° eastward in *Gemini* during the two months. On June 24th it is in conjunction with *Mercury,* the latter planet being about 2° to the north.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these Publications, and the Publication Committee has acted favorably upon the suggestions.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

INVESTIGATION OF ECLIPSING BINARIES, BY RUSSELL AND SHAPLEY.[1]

BAUSCHINGER remarks in his *Bahnbestimmung* that the relation between magnitudes, size, luminosities, and elliptic and photometric elements of eclipsing binaries are too complicated for a general theory. It is our purpose to show how far the problem is determinate and to develop formulæ and tables for determinate cases. In the most general case the relative orbit will be eccentric, and the two component masses will differ in size and brightness. The bodies may be elongated by mutual attraction, partially brightened by mutual illumination, or apparently darkened toward the limbs of the disks. There will be at least thirteen quantities to be determined—semi-major axis, eccentricity, inclination, longitude of periastron, period, epoch, two radii, two luminosities, ellipticity, reflection, and limb-darkening factors. The last mentioned may be deferred for special investigation. Two of the quantities depend upon the parallax, two upon inspection of the light-curve, and two upon particular photometric measures. Six remain to be determined by formulæ and constants of the light-curve.

The discussion is divided into several parts: First, solution for spherical stars and circular orbits; second, the corresponding tables; third, eccentric orbits; fourth, ellipticity of the stars; fifth, reflection, limb darkening, and densities.

The simplified problem discussed in the first part is stated as follows:—

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[1] Abstract from the *Astrophysical Journal*, [illegible], 315, [illegible], 54, 133, 239, 269, 385.

Two spherical stars, appearing as uniformly illuminated disks, and revolving about their common center of gravity in circular orbits, mutually eclipse one another. It is required to find the relative dimensions and brightness of the two stars, and the inclination of the orbit, from the observed light-curve.

Under these conditions, the two minima of the light-curve will be symmetrical and separated by exactly half the period; a total or annular eclipse produces a constant phase at minimum; the two minima will be of equal duration, but usually of unequal depth; the deeper minimum corresponds to the eclipse of the star which has the greater surface intensity by the other.

The discussion now distinguishes two cases—that of central eclipse giving constant phase at both primary and secondary minima, and that of partial eclipse giving no constant phases. In concluding the discussion of the first case, it is remarked that the method of solution is direct and simple, involving a very moderate amount of numerical work; the light-curve may be found without the necessity of computing the elements, and with two or three trials may be determined so as to represent the whole course of the observations, making the laborious solution by least squares superfluous except in the case of observations of unusual precision. Such a solution itself is much simplified if the constants defining the light-curve, instead of the elements of the system, are treated as the fundamental unknowns, as the coefficients of the equations of condition may be easily found graphically with the aid of data already computed. The elements may be found, at any stage of the process, by a few moments' calculation from the constants defining the light-curve.

In passing to the second case, which concerns partial eclipse, the previous methods cannot be used, and the following conclusion is reached: To the degree of approximation attained by any existing photometric measures, the problem of determining the elements of an eclipsing variable solely from the light-curve of a primary minimum without constant phase is indeterminate. Two of the required quantities cannot be rigorously deduced.

However, an equation is derived which, though not rigorously exact, must be very nearly satisfied in the case of all light-curves arising from partial eclipse. Having given any observed light-curve, the values of the coefficients may be determined in the manner described (omitted in this abstract), and a theoretical light-curve be found which closely represents the whole course of the observations. Knowledge of this light-curve, however, does not enable us to find the elements, but only a relation between them. Unless the secondary minimum has been observed, we can go no farther. But if we know the brightness at both minima, we have another relation or equation. Solution of these two equations gives the two required quantities,—namely, the ratio of the radii and the percentage of maximum eclipse.

When both minima are of very small depth, the indeterminate character of the solution is pronounced. The exact form of the light-curve for a shallow minimum is especially difficult to fix by observation. It follows that eclipsing variables of small range, such as have been recently discovered with the selenium photometer, present a problem which can be solved only by the addition of other data than those derivable from the light-curve. The ratio of the surface brightness of the components is the same as the ratio of loss of light at the two eclipses. This value in connection with an estimate from spectroscopic observation of the difference of magnitude of the components, determines the ratio of the radii. Whenever the latter quantity and the percentage of maximum eclipse have been found, the determination of the remaining elements is simple.

The above method of solution of the problem presented by a partial eclipse, though not rigorously exact, is sufficiently accurate to be adopted as final, unless the observations are unusually numerous and precise. If it seems desirable to proceed farther, the light-curve, including both primary and secondary minima, should be computed from the assumed elements. If it does not represent the observations sufficiently well, the assumed constants may be varied until satisfactory. As before, the elements need not be computed until a satisfactory light-curve has been found.

The second part of the investigation contains tables and explanations. Since the majority of eclipsing binaries have practically circular orbits, the above methods and tables will be more frequently used than those of the other parts of the discussion. The former have been applied to the eclipsing variables W *Delphini*, W *Ursæ Majoris*, and W *Crucis*, and the results are summarized as follows:[1] The light-curves shown in the figures are simply graphical representations of the tables. The curves are in all cases those corresponding to the finally adopted elements. The agreement between theory and observation is excellent. The "rectified" light-curves show how a curve of the *β Lyræ* type is transformed into one of the ordinary *Algol* type by the application of the correction for the ellipticity of the stars. (The latter process is developed in Part IV.)

The third part considers eccentric orbits. Analogy with orbits of spectroscopic binaries of similar period leads us to expect that the actual orbits of eclipsing variables will often show eccentricity. This is confirmed in several cases by displacement of the secondary minima from the position midway between the primary minima. Elements computed from the light-curve on the assumption of a circular orbit will differ from the true values. But for small eccentricity simple equations can be found which express very approximately the relation between the true and computed elements. In using these equations, since the secondary minima is often shallow, two cases occur, according as the principal minimum does or does not show a constant phase. In the first case the light-curve may be found which best represents the observations. Only the times of the four contacts need be computed at first and the work involved is small. If the principal eclipse occurs near periastron and is nearly grazing, the secondary eclipse may be partial. In the second case, with principal minimum showing no constant phase, the problem is more complicated, for two necessary quantities are unknown. But a certain sequence of operations starting with circular elements, may lead to acceptable values; if the range of values is wide, the problem is nearly indeterminate.

Part four deals with the ellipticity of the component bodies. *β Lyræ* is a classic example. The light changes are continuous and the brightness is greater between minima than before or after eclipse. This phenomena is reasonably explained by the assumption that the stars are elongated by their mutual attraction. The figure is probably nearly ellipsoidal. If the components are equal in mass and density, they will be similar in form. Two prolate spheroids is the basis of calculations in this investigation. (The methods of finding the ellipticity are explained.) Having found the ellipticity, the light-curve may be "rectified," i. e. the apparent influence of ellipticity may be removed. The procedure is then the same as for spherical bodies. When the orbit is eccentric, complications ensue, but a good approximation may be obtained by neglecting certain irregularities and proceeding as above.

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[1] *Astrophysical Journal*, **36**, 133.

The fifth part discusses mutual reflection of the two components, the darkening toward the limb of a disk and the densities of the bodies. It is improbable that the bodies appear as uniformly illuminated disks of constant surface brightness. It is likely that they appear, like the Sun, to be brighter at the center than at the limb and that each star is brighter on the side which is heated up by its companion's radiation. Direct evidence of the last phenomenon has been found in *Algol*, RT *Persei*, and Z *Draconis*. Few stars have been studied as carefully as these, but sufficiently accurate observations may show the phenomenon to be general.

Certain relations are available for freeing the light-curves from the effects of reflection so that it may be discussed as usual. Prolateness of the bodies complicates the expressions; but the curve may first be "rectified" to remove effects of ellipticity. The effect of eccentric orbit may be represented by a simple harmonic term in connection with "reflection."

The densities of the component bodies cannot be computed unless the ratio of masses is known. This can be found in cases of double spectra, and otherwise. The densities are then expressed in terms of the mass-ratio, the period, and the radii.

The actual law of darkening toward the limb is unknown, but one may be assumed,—for instance, that applied to the Sun by SCHWARZSCHILD. Solution can be obtained by means of further tables. They will be twice as extensive as those already given, since the light-curves of annular and total eclipse differ with non-uniformly illuminated disks. The relations already developed for the case of partial eclipse may or may not be applicable. Ellipticity with darkening complicates the problem. The darkening should be greater when we see the prolate spheroid end on, than when it is side on. The variation in light will be increased and the ellipticity computed on the assumption. of uniform surface brightness will be too great.

The darkening toward the limb has been further discussed in later papers[1] and the tables constructed. They enable the solutions to be made as easily as in the case of uniformly illuminated disks, provided the eclipse is total. The formulæ and tables are applicable only in those cases where there is a constant phase at minimum and the eclipsing star is the larger. But other methods are available for partial eclipses. The tables have been applied to the totally eclipsing variables W *Dephini,* S *Cancri,* SW *Cygni,* and U *Cephei.*[2] Solutions have also been made with the tables for uniformly illuminated disks. The conclusion is that the former results are more satisfactory, indicating that darkening at the limb exists in stars of spectral class A, but the difference in the curves is too small to determine the amount of darkening, even with the best existing photometric observations.

The discussion of annular and partial eclipses in connection with darkening of the limb has involved much labor. The light curves for non-central eclipse may be derived from that for central eclipse. Since annular and partial eclipses cannot be distinguished by inspection of the light-curves, they are discussed together for the determination of the elements.

A summary of the eclipsing-variable theory here developed is given at the end of the series of papers. The methods will probably be of use for many years to come in the practical solution of this problem. G. F. PADDOCK.

THE BRIGHTNESS AND TEMPERATURE OF STARS.

Two essential problems in astrophysics are the determination of the brightness and of the temperature of stars, because of their concern with the sequence and transition of spectra. The question is, Which is the hotter and brighter—the blue, yellow, or red star? Investigations have usually been based upon inferences and assumptions, but there are certain cases in which the luminosity can be definitely computed. From the relations of stellar light and magnitude, is deduced the equation—

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[1] *Astrophysical Journal,* **36**, 239, 385.
[2] *Astrophysical Journal.* **36**, 269.

$$\pi R\sqrt{l} = 10^{-\frac{m+0.24}{5}}$$

in which π is the parallax, R the radius, m the magnitude, and l the intrinsic luminosity or brightness of a star whose radius equals the Sun's radius. Observations of eclipsing binaries determine the radii of the components, particularly when both components are luminous and give both primary and secondary light minima. If the system gives double spectra, the parallax is thence determined, and l is then found by means of the above equation. Without double spectra, but with a correspondence of spectra and luminosity with the Sun or other known body, the parallax may possibly be determined by the above equation. This, however, will be a rare case. It is likely that the parallax will be known for numerous stars in the future. Hence l, the star's intrinsic luminosity, will be the quantity actually to be sought by means of the above equation. Photometric observers are finding that numerous variables have double minima. The combination of photometric and spectrographic observations and elements is needed for as many stars as possible.

Temperatures can hardly be determined unless we know or assume a law of relation between l and T (absolute temperature). However, formulæ representing these laws have been derived for the theoretical perfect radiator under terrestrial or laboratory conditions, and several attempts have been made to apply the formulæ to star light. Wilsing, Scheiner, Schwarzschild, Nordman, and Rosenberg have published series of relative temperatures for the bright stars. Each work is based upon measures of difference of intensity of red, yellow, and blue light received from stars. The difference of intensity has been measured either by photometer and photograph, or from spectrum photographs. An adaptation of Planck's radiation formula,—

$$E = \frac{C_1}{\lambda^5\left(e^{\frac{c_2}{\lambda T}} - 1\right)}$$

which expresses the radiated energy E as an exponential function of wave-length λ and absolute temperature T then gives values for T corresponding to each stellar measure. The most recent results are those of ROSENBERG[1] derived from Göttingen observations with a prismatic camera of the seventy brightest northern stars. His results differ only in a definite ratio from those of WILSING and SCHEINER.

The stellar measures are expressed in differences of magnitude and reduced to a basis of zero difference for the Sun spectrum. The derived temperatures are relative to the Sun's temperature of about 5000° (absolute), which has been derived by PLANCK's formula from ABBOT's bolometer measures of the Sun's spectrum intensities and PASCHEN's constants of a perfect radiator. The results for some of the conspicuous stars are: *Sirius*, 27,000°; *Vega*, 22,000°; *Algol*, 12,000°; *Altair*, 10,000°; *Procyon*, 7,000°; *Polaris*, 5,000°; *Capella*, 4,500°; *Arcturus*, 3,000°; *Betelgeuze* and *Aldebaran*, 2,000°. ROSENBERG has plotted the reciprocals of his temperatures against the series of classes of spectra as defined by Miss MAURY and by VOGEL. The plots show that there are more differences of spectrum among the highest and lowest temperatures than among the intermediate temperatures. The general results of the investigation are that the helium stars are the hottest, and the reddest stars of banded spectra the lowest in temperature. In other words, the derived sequence of temperatures follows the sequence of spectral class. G. F. PADDOCK.

March, 1913.

ON THE SPECTRUM OF THE NEBULA IN THE PLEIADES, BY V. M. SLIPHER.[2]

Since its discovery by TEMPLE in 1859, the *Merope* nebula has been an object of unusual interest to astronomers. In the telescope it is so faint and diffuse that in the old days, before the advent of the camera as an aid to the astronomer, its existence was disputed and held in grave doubt by many observers. In fact, a number of the profession may be said to have been divided into hostile camps on this question, and in the skirmishes which resulted the pages of astronomical periodicals were occasionally enlivened by passages which broke through that cold formality which is supposed to mark the expression of scientific opinion. Happily those strenuous days are now past. Among the early achievements of the photographic plate was the proof, satisfactory to the most skeptical, that the nebula is there, a bundle of interlacing wisps weaving together the entire group of the *Pleiades*, and pointing to the close physical connection of the members of this group of stars. Curiously enough, the camera, in confirming TEMPLE's discovery, proved as well that his idea of the nebula was, in one respect, quite erroneous. He observed the nebula only close to and to the south of *Merope*. GOLDSCHMIDT in 1864 described the cosmical cloud as surrounding the whole group of the *Pleiades*. Commenting on this observation, Professor TEMPLE remarked: "But this is an optical illusion, and in another letter I shall, with your permission, proceed to prove this by the description of a false image in the telescope, a curious phenomenon hitherto unexplained." GOLDSCHMIDT's remarkable observation is of course amply confirmed by photography.

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[1] *Astronomische Nachrichten*, **193**, 358, 1913.
[2] *Lowell Observatory Bulletin*, **2**, 26, 1912.

We must ask the indulgence of the reader for this somewhat extended excursion into a phase of the history of this nebula which has no direct bearing on the subject-matter of the article under review, but we offer in extenuation of our garrulity the fact that we have called attention to the doubt and uncertainty with which this nebula was for years regarded, a view-point quite in keeping with the mystery which has attached itself to the *Pleiades* group, among races civilized and savage, since before the beginnings of history. We may therefore regard it as a professional practice backed by precedent to accept with caution, until fully confirmed, discoveries associated with this cluster.

Dr SLIPHER's paper deals with a photographic observation of the spectrum of the nebulous filaments near the star *Merope*. Two spectrograms were secured with a spectrograph attached to the 24-inch refractor of the Lowell Observatory. The first exposure was of five hours' duration and the second of twenty-one hours. The slit was located in the one case about 1½′ of arc south of the star and in the other 3′ northeast, the orientation being east and west for both observations. The discussion is based on the second spectrogram secured. We can do no better than to quote Dr. SLIPHER's description of this plate.

"The second spectrogram, while not strong, contains a perfectly legible record. It is a continuous spectrum crossed by strong hydrogen lines—Hβ, Hγ, Hδ, Hϵ, and Hζ showing, and fainter helium lines, those at 4026, 4381, and 4472 (combined with 4481), being recognizable. It contains no traces of the bright lines found in the spectra of gaseous nebulæ. The hydrogen lines are much more prominent than are the helium lines, and the whole spectrum is a true copy of the brighter stars of the *Pleiades*."

To satisfy himself that the recorded spectrum did not have its origin in light from *Merope* scattered in his telescope, Dr. SLIPHER made an equivalent exposure close to *Sirius*, and finding no disturbing factor, assumed the plate record to represent the spectrum of the *Pleiades* nebula. A further confirmation of this view he finds in the fact that the spectrum is not uniform over its full breadth, but fades suddenly at one edge, as though the slit had projected beyond the bright part of the nebula.

Upon the basis of this spectrogram the author indulges in some speculations, throwing out the suggestion that the light of the nebula may be diffused starlight, originating with *Merope*. In other words, the nebula does not shine by its own light, but is an aggregation of non-luminous material *lighted up* by *Merope* and other stars of the *Pleiades* group. Dr. SLIPHER's figures show that, in the part of the nebula which he observed, *Merope* would appear as a star of about — 11 magnitude, and *Alcyone* two or three magnitudes fainter; that is, the former would be about as bright as the full Moon. As it is easy for us to see thin clouds by moonlight, there can hardly be any criticism of this theory on the basis of insufficiency of illumination. Dr. SLIPHER's explanation parallels exactly the theory of the nebulosity surrounding *Nova Persei* proposed by SEELIGER, KAPTEYN, W. E. WILSON, and others.

Dr. SLIPHER's paper is interesting and suggestive, and his audacity in attempting this observation must win the admiration of his colleagues, but we believe that astronomers will await his confirmation of these preliminary results before making them the basis of extended speculations. Unfortunately, the constants of his spectrograph are not explicitly stated, so that we are unable to judge of its efficiency for observations of very faint spectra. Few persons unfamiliar with spectroscopic observation fully appreciate the extreme faintness of the spectrum of an object of this class and the resulting difficulties of observation.

W. H. WRIGHT.

ON THE SHORT-PERIOD VARIABLE, SU DRACONIS, BY C. MARTIN AND H. C. PLUMMER.[1]

This star was selected for observation in order to test the reality of certain secondary fluctuations which had been encountered in the course of the work with the Dunsink 15-inch reflector. The method employed was to give a long exposure in the region of the variable star, getting images with sensible discs, the inner nuclei of which were measured with the micrometer. Sixty-seven measurable exposures were made, extending over a period of about two months. It was found that the relation between magnitude and diameter for the Dunsink reflector could be expressed by $m = a - b D^{½}$. By plotting m (magnitude) and $D^{½}$ (diameter) for the standard stars chosen in the neighborhood of SU, and drawing a straight line through the points, m could be read off corresponding to the measured $D^{½}$ of the variable. From the maximum of this series combined with that found by Professor SEARES in 1908, the value of the period was found to be $0^d.6604347$. When the observations were plotted it was seen that there was, besides this period, a secondary variation in about one-sixth the time. Attempts to determine this sub-period were unsuccessful. By spherical harmonics, the following analytic expression was derived, which represents the observations very closely: $m = 10.02 + .34 \sin(\theta + 239°.9) + .19 \sin(2\theta + 271°.9) + .15 \sin(3\theta + 301°.6) + .05 \sin(4\theta + 345°.4) + .03 \sin(5\theta + 160°.0) + .06 \sin(6\theta + 11°.7) + .03 \sin(7\theta + 267°.8) + .02 \sin(8\theta + 244°.0) + .02 \sin(9\theta + 236°.8) + .01 \sin(10\theta + 236°.7) + .01 \sin(11\theta + 146°.0)$. A comparison of curve and observation led to the conclusion that the error of observation was probably less than ± $0^m.03$. The general characteristics of the visual and photographic results are the same, but details differ considerably in the two methods. A. M. HOBE.

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[1] [illegible] Notices, January, 1913.

COMPARISON OF OBJECTIVE PRISM AND SLIT SPECTROGRAMS, BY ANNIE J. CANNON.[1]

The object of this paper was to see whether or not there would be any differences in classifying slit spectrograms and objective prism photographs. For this purpose spectrograms were obtained from Yerkes, Lick, and Allegheny observatories. These spectrograms, of all types of stars, were classified independently, all identifying marks being concealed, and the results compared with the Harvard objective prism classification. A list, classified by Dr. KOHLSHÜTTER, was also sent from Mount Wilson and these Miss CANNON compared in the same way. The Yerkes were one-prism plates and included the same part of the spectrum as the objective prism. The Lick were three-prism plates and gave too great a dispersion for general purposes of classification, but were splendid for getting relative intensities of lines. The Allegheny were one-prism plates and were excellent for general classification, but did not show the faint, hazy, dark lines so clearly as the objective prism. The general conclusion was that there were only slight differences between the objective prism and slit-spectrogram classifications, the tendency being to put the slit spectrograms a little later in the scale. A. M. HOBE.

VOLUME XX OF THE ARGENTINE NATIONAL OBSERVATORY AT CÓRDOBA.

This publication contains the results of the meridian circle observations which were made in the years 1885 to 1890, inclusive, under the direction of the late Dr. J. M. THOME, and which were reduced under his supervision.

The catalogue includes 5.791 stars, all of which, with the exception of sixty-eight, are south of the equator. The list includes the 303 stars which make up the fundamental catalogue for the southern Gesellschaft zones. Observations of the greater part of the bright stars were included in the *Argentine General Catalogue*, Volume XIV, of the same observatory. The faint stars of this later catalogue were mostly observed as part of a scheme to provide a network of star places, one every 10′ of declination, at intervals of two minutes of right ascension. Sufficient stars do not exist, of the brightness possible to observe with the original meridian circle at Córdoba, to complete such a design. The *Zone Catalogue*, though giving fairly good distribution, leaves some gaps, most of which, however, it would not be possible to fill with available stars.

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[1] *Annals of Harvard College Observatory*, Vol. LVI, No. VIII.

The catalogue includes the fundamental stars used for clock errors and for the determinations of azimuth. It contains reference, by numbers, to the *General Catalogue* and the *Zone Catalogue* of Córdoba, and to the several parts of the visual and photographic *Durchmusterung* of the southern sky. For the brightest stars, those designated by letters in the constellations, no references are given. For many of these bright stars, more than one value of the magnitude has been printed, though the practice usually followed has been to give the magnitude adopted by some standard authority. The *Uranometry* affords such a standard, and certainly none of the estimates of bright stars made by meridian-circle observers can be considered as trustworthy in comparison with it.

The improvement in the financial condition of the country, and a more liberal policy to the observatory on the part of the government, have finally remedied the delay in the publication of these observations, made more than twenty years ago. Of the men attached to the observatory at that epoch, JOHANN DRELESSEN is the only member of the present staff.

R. H. TUCKER.

March 10, 1913.

"EXTRA-MERCURIAL" PLANETS.

A great deal has been written on BODE's well-known law of planetary distances, but it is doubtful if a more novel aspect of the law has ever been developed than that which is given by Professor C. V. L. CHARLIER in his paper, "Das Bodesche Gesetz und die sogenannten intramerkuriellen Planeten."[1]

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[1] *Astronomische Nachrichten*, 193, 269, 1913.

This law of planetary distances is regarded by most astronomers as simply a curious coincidence, but POINCARÉ has shown that the law prescribes that the planets were separated from the original solar nebula at equal intervals of time, so that there is the possibility that such a law might have a real mechanical significance. Why the planets should have separated at equal intervals of time, however, remains without explanation.

As ordinarily written, the law of BODE is derived as follows: Writing down the progression 0, 3, 6, 12, etc., and then adding the constant quantity, 4, the resulting quantities will give the relative distances of the planets from the Sun; to obtain these distances in terms of the Earth's distance, the values may be divided by 10.

	0	3	6	12	24	48	96 etc.
Adding 4	+4						
Divide by 10...	0.4	0.7	1.0	1.6	2.8	5.2	10.0 etc.

This gives 0.4 for *Mercury's* distance, unity for that of the Earth, and holds well for all the planets except *Neptune*.

Now it has ordinarily been assumed that to obtain the probable distance of an intra-mercurial planet, by means of BODE'S law, the series should be extended to the left by the addition of a term, —3, giving 0.1 for the relative distance of such a body. But, as pointed out by GAUSS, if this were a true geometric progression the first term should be 1.5 instead of 0, and CHARLIER gives for the mathematical expression of BODE'S law the following formula:—

$$\text{Distance} = 0.4 + 0.3 \times 2^n,$$

where n is a whole number. The value $n = 1$ gives the Earth's distance, $n = 0$ that of *Venus*, while for the distance of *Mercury* $n = -\infty$. According to this formula, then, there would possibly exist between *Venus* and *Mercury* an infinite number of planets, with the distances,—

0.550, 0.475, 0.438, 0.419, 0.409, 0.405, 0.402........0.400

This *Saturn*-like ring of small bodies, with its inner limit at the mean distance of *Mercury*, would not be equally distributed, but the majority of these planetoids should be found at the two libration points which make equilateral triangles with

Mercury and the Sun. Such a ring of planetoids would serve to clear up the discrepancies in the motion of the perihelion of *Mercury*. CHARLIER applies a similar formula to the satellites and rings of *Saturn*. He points out that such bodies as these planetoids could best be searched for at the time of a total solar eclipse, though it should be possible to institute such a search in stations near the equator at any time.

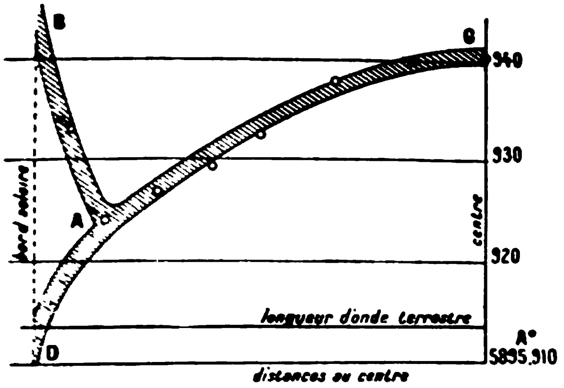
H. D. CURTIS.

March, 1913.

A. PEROT: WAVE-LENGTH OF SOLAR D_1.[1]

In a former paper it was shown that near the center of the Sun the b_1 line of magnesium has a velocity of $+ 1.57^{km}$ per second, indicating that the absorbing magnesium is falling in toward the center of the Sun. It was suggested that this may be due to the fall of particles of negative electricity which may drag the absorbing atoms along with them.

The wave-length of D_1 was measured by interference methods at different points along a line from the north to the south pole of the Sun and bisecting the apparent disk. At the center of the Sun, *G* in the figure, the wave-length is 5895.941 Ångstroms; it decreases as we go outward along the radius toward the pole, until about 60° of latitude, *A*, where, due to tangential effect, other than rotation, the curve reverses, and the wave-length increases on to the pole *B*. Neglecting the tangential effect and continuing the first portion of the curve as a smooth



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[1] Comptes Rendus, 156 326, 1913.

sweep down to D, it gives the wave-length at the edge as 5895.914, corresponding to a difference of 1.37^{km} from the center. The wave-length of bright D_1 as measured in a laboratory flame is 5895.930. The flame *absorption* D_1 was measured and found to be 5895.9155, which agrees within experimental errors with the extrapolated value for the Sun's limb.

P. W. MERRILL.

UPON THE DEPENDENCE OF THE DISTRIBUTION OF STARS OF DIFFERENT SPECTRAL TYPES, AND OF THE MEAN PARALLAXES OF THE STARS UPON THE GALACTIC LATITUDE.

Under this title (in German) Professor H. SEELIGER publishes in the *Astronomische Nachrichten*[1] the general conclusions arrived at in a research upon stellar distribution. The detailed results will be published later, probably in the Proceedings or Transactions of the Munich Academy of Sciences, which contain his three earlier papers on the same general subject.

Referring to these earlier researches, Professor SEELIGER says that in the formulæ he derived for the numbers of stars of given apparent magnitude and for their mean distances the facts that the stars are not uniformly distributed in space and that they are not all of the same luminosity (*Leuchtkraft*) have been taken into account with their proper weights. "That thereby," he adds, "the correct foundations for all stellar astronomical researches have been formulated cannot be gainsaid."

The present paper refers to a study of what SEELIGER calls the "typical" stellar system (i. e. one which assumes that the plane of the Milky Way is the plane of symmetry in the system), and investigates the dependence, if any, of the distribution of the stars of different spectral types, of their mean parallaxes, etc., upon the galactic latitude, or, in other words, upon their distance from this fundamental plane. His earlier formulæ, referred to above, gave expressions for a function $\phi(\iota)$, and for D, in which ι represents the relative frequency of the various apparent stellar magnitudes if all of the stars were at the same distance from us,[1] and *D*, the density of star distribution in a unit volume of space.

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[1] *Astronomische Nachrichten*, **193**, 161, 1912.

By the use of these two formulæ, with proper choice of the variables and constants involved, SEELIGER finds that he can represent quite approximately the distribution of the stars of different spectral types to magnitude 6.25 tabulated by PICKERING from actual count on the Draper memorial photographs. He also finds that, by a similar process, he can reproduce, in a general way, the average radial velocities given by CAMPBELL for stars of different spectral type. Investigating the mean parallaxes of the stars of a given magnitude with the aid of these formulæ, he concludes that the parallaxes increase as we proceed from the pole to the plane of the Milky Way, so that, for example, the average star of 8.5 apparent magnitude in the Milky Way is 2.34 times as distant as one of the same magnitude at its pole.

SEELIGER's general conclusions are that the Milky Way is a fundamental part of the structure of the entire stellar system and that this system is limited in extent (conclusions already arrived at in his earlier researches); that the function $\phi(\iota)$ has the same form in all parts of the stellar system, and, finally, that the correspondences now developed confirm, so far as they go, the validity of his formulæ. R. G. AITKEN.

March 10, 1913.

Sur les Spectres des Nébuleuses et sur les Analogies qu'on en peut tier. Note de M. Jean Meunier, presentíe par M. Armand Gautier.[2]

This article represents an attempt to correlate the spectra of the nebulæ with the dark-line spectrum of the Sun. As a basis for the comparison, the author offers on the one side a list of eight nebular lines, gleaned from some casual remarks on the spectra of the nebulæ in the *Annuaire du Bureau des Longitudes*. The selection of lines is unfortunate, as it includes some of the fainter of the fifty or more well-known nebular lines and omits many of the stronger. One of them, 4481 A, does not appear in those numbers of the *Annuaire* which we have consulted, and such a line has not, to our knowledge, been observed in a nebula. The treatment of the subject has the merit of originality, but evidences so limited an acquaintance with the subject of astronomical spectroscopy as hardly to call for serious criticism. For instance, one is accustomed to regard the existence of helium in the nebulæ as proved by the exact coincidence of the principal lines of its spectrum with lines in the spectra of the nebulæ, but M. MEUNIER completely ignores the claims of this element, and identifies the nebular lines in question with iron lines four or five Ångstroms away. We fear that the paper will not carry much weight with the working spectroscopist, and, as we have said, it seems to have few claims to serious consideration. It is reviewed chiefly for the purpose of calling attention to the danger which attends the publication of ill-considered articles by a journal having the prestige of the *Comptes Rendus* of the Paris Academy. Persons unfamiliar with certain phases of astrophysics might well be led astray in their notions of the present state of the science.

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[1] SEELIGER takes this unit distance as the one expressed by the stellar parallax [illegible] and calls it "*Siriusweite*," though the best value of the parallax of *Sirius* [illegible]

[2] *Comptes Rendus*, 156, 391, 1913.

W. H. WRIGHT.

March, 1913.

THE USE OF GALACTIC CO-ORDINATES FOR THE FIXED STARS.

Mr. INNES devotes Circular No. 2 of the Union Observatory[1] of South Africa to an argument in favor of the use of galactic co-ordinates in defining a star's position in the sky instead of the usual equatorial co-ordinates, right ascension and declination. The advantages to be gained are:—

"(1) The place of any star in any catalogue will only differ from [that in] another catalogue by errors of observation and by proper motion, therefor catalogues will be comparable without preliminary calculation.

"(2) The reduction to apparent place, and vice versa, is shorter than the present method.

"(3) The stars are referred to their natural plane of reference and facts of stellar distribution and drift, which are at present hidden, are at once recognized."

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[1] As a consequence of the political reorganization of the English provinces of South Africa, the Transvaal Observatory has become the Observatory of the Union of South Africa. Mr. R. T. A. INNES continues in charge as director, and his address is Johannesburg, Transvaal, Union of South Africa.

Taking for the position of the galactic pole the co-ordinates given by Newcomb: R. A. = 191°.1; Decl. = + 26°.8, and for the solar apex the position suggested by Campbell as most convenient: R. A. = 270°; Decl. = + 30°, and assuming the point of departure for galactic longitudes to make the longitude of the solar apex 0°,—Innes gives the formulæ, with illustrative examples and specimens of tables, for all the cases arising in the conversion of co-ordinates from one system of reference to the other.

Notes in this department of the *Publications* are designed to be abstracts merely, and, in general, to omit criticism, but I think it may be permissible to add that, though there are many obvious objections to it, there is also much to be said in favor of such a change as Mr. Innes suggests. He quotes Professor Turner's statement, made in 1843—"Right ascension and declination are a necessity of meridian and equatorial observations, but only complicate any discussion of the places of the stars." It would be easy to get similar opinions from all astronomers who have engaged in investigations of stellar motions. As a matter of fact, a considerable part of the computation involved in such researches as those published in recent years by Kapteyn, Boss, Campbell, and others has consisted in the conversion of the star places used from equatorial to galactic co-ordinates.

R. G. Aitken.

March, 1913

Distribution of the Spectroscopic Binary Stars.

It has been shown that seventy-four of the ninety-three known *Algol*-type variable stars are found within 30° of the plane of the Milky Way. This condensation toward the Milky Way is more than twice as great as that shown by the stars to the ninth magnitude taken as a whole. The *Algol* variables are all supposed to be spectroscopic binaries, though at present only the brighter ones have been observed for radial velocity. M. P. Stroobant has now investigated the distribution of the 306 spectroscopic binary stars included in Campbell's Second Catalogue, to determine whether a similar tendency is shown by them. His results are printed in the *Comptes Rendus*, Paris Academy,[1] and may be summarized briefly as follows:

Two hundred and seventeen of these stars lie within 30° of the central plane of the Milky Way, but 108 of them are Class B stars. Since the known spectroscopic binaries are, with few exceptions, visible to the naked eye, we must compare this distribution with that of the naked-eye stars. Taking the latter from HOUZEAU, STROOBANT finds that 2,565 of the 5,719 lie within galactic latitude limits ± 30°. Stated as percentages, about 40 per cent of all naked-eye stars, about 71 per cent of all known spectroscopic binary stars, and about 55 per cent of the latter when the Class B stars are excluded, lie within 30° of the plane of the Milky Way. The observed condensation of the spectroscopic binaries toward this plane is therefore largely, but not wholly, due to the preponderance of the Class B binaries.

R. G. AITKEN.

March 13, 1913.

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[1] *Comptes Rendus,* **156,** 37, 1913.

GENERAL NOTES.

The sixty-fourth meeting of the American Association for the Advancement of Science was held at Cleveland, Ohio, from December 30, 1912, to January 4, 1913. Professor E. C. PICKERING, director of the Harvard College Observatory, was the presiding officer, but, under the rules of the association the annual address was delivered by the retiring president, Dr. C. E. BESSEY. Professor PICKERING, in turn, will deliver the address at the next annual meeting.

Professor E. B. FROST[1] was vice-president of Section A, Mathematics and Astronomy, and presented an address on the subject "The Spectroscopic Determination of Stellar Velocities, Considered Practically." The Astronomical and Astrophysical Society of America, the American Mathematical Society, and the American Physical Society held a joint meeting with Sections A and B. The address of Professor R. A. MILLIKAN, vice-president of Section B, Physics, on "Atomic Theories of Radiation,"[2] will also be of interest to astronomers.

The Council of the association adopted a resolution creating a committee of thirty members to be known as the "Committee on the Pacific Coast Meeting," whose duty it shall be to consider the relations of the association to the exposition and, if desirable, the presentation of scientific programs. Director W. W. CAMPBELL of the Lick Observatory was made chairman of this committee, the membership of which includes many members of the scientific departments of Stanford University and of the University of California. The San Francisco meeting is to be held in the summer of 1915; the meeting in December, 1913, will be held at Atlanta, Georgia, and that of 1914 at Philadelphia.

The International Union for Solar Research will hold its next triennial meeting at Bonn, Germany, beginning August 1, 1913. On Wednesday of the following week (August 6th) the Astronomische Gesellschaft will hold its meeting at Hamburg, Germany.

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[1] Professor FROST is spending the year in Europe. His address was read by Professor J. A. PARKHURST.

[2] The address is printed in *Science*, 37, 119, 1913.

A new board of editors assumed charge of the well and favorably known English astronomical journal, *The Observatory*, at the beginning of the present year. *The Observatory* was "founded in 1877 by Mr. (now Sir WILLIAM) CHRISTIE, who handed it on to Mr. E. W. MAUNDER a year or two later. In 1884 Mr. MAUNDER was joined by Messrs. A. M. W. DOWNING and T. LEWIS for three years, after which Professor TURNER took it over jointly with Dr. COMMON till 1892 and afterwards with Messrs. T. LEWIS and H. P. HOLLIS till 1893, since when the two latter have been sole editors." The new editors are Messrs. F. J. M. STRATTON, A. S. EDDINGTON, and S. CHAPMAN. It is their intention not to change the general character and arrangement of the magazine.

The Observatory for January, 1913, records the death of Mr. S. A. SAUNDER, for many years senior mathematical master at Wellington College, and long a member of the Royal Astronomical Society. Mr. SAUNDER was known as an authority on selenography, and his principal astronomical work related to the accurate measurement, from photographs, of the positions of points on the Moon's surface. "In 1900 the number of points on the Moon whose places were known with any pretension to accuracy was 162, due mainly to LOHRMANN and MÄDLER. In 1910 the number of points was 3,012, of which 2,885 were due to SAUNDER. The probable error of a measure had been reduced from 7″.02 to 0″.15."

It was Mr. SAUNDER's intention to establish a definitive system of lunar nomenclature, and this scheme was undertaken in co-operation with Professor JULIUS FRANZ, director of the observatory at Breslau. *Science,* in the issue for February 21, 1913, records the death of Dr. FRANZ also, but it is understood that this plan was practically completed, and that as soon as a new map of the Moon, now in process of construction, has been completed the definitive nomenclature recommended by these eminent selenographers will be transferred to it.

The National Academy of Sciences will hold an adjourned meeting on April 22d-24th to celebrate the fiftieth anniversary of its foundation. In addition to the American speakers, three European men of science have been invited to give addresses—Professor J. C. KAPTEYN, Professor ARTHUR SCHUSTER, and Professor THEODOR BOOHI. Professor KAPTEYN's subject will be "The Structure of the Universe."

A great many lectures have been given within the past few months by prominent astronomers in this country and in Europe in which the results of recent researches on the motions and distribution of the stars have been presented to general audiences. Among these we may note a series of three on "The Movements of the Stars" begun on February 25th at the Royal Institution by Professor H. H. TURNER.

Major E. H. HILLS has been appointed honorary director of the Durham University Observatory.

The *Astronomische Nachrichten* has begun to issue a *Literarisches Beiblatt*, which contains short abstracts of astronomical publications—both books and articles in periodicals. The last number issued is Number 6, which was closed on January 1, 1913.

The Astronomical Society of Mexico has decided to offer a medal and diploma to any astronomer who discovers a comet The medal will be known as the Carolina Herschel Medal.

Science states (March 7, 1913) that an anonymous donor has offered the University of Cambridge (England) £10,000 towards the endowment of a chair of astrophysics.

The Lalande Prize of the Paris Academy of Science has been awarded to Professors H. KOBOLD and W. WIRTZ for their work on the determination of the motions of nebulæ. The Academy awarded the Valz Prize to M. ALEXANDRE SCHAUMASSE for his work on comets, and the Jannsen Prize to M. A. PEROT for his work in spectroscopy, particularly with reference to solar phenomena.

From the list of members and correspondents of the Academy, printed in the first number of the *Comptes Rendus* for 1913, it appears that only four Americans are now corresponding members. Three of these—G. W. HILL, E. C. PICKERING, and G. E. HALE—are astronomers. The fourth is A. A. MICHELSON, the physicist.

The gold medal of the Royal Astronomical Society has been awarded to M. H. A. DESLANDRES for his investigations of solar phenomena and other spectroscopic work. The Jackson-Gwilt Medal has been awarded to Rev. T. H. E. ESPIN for his observations of the spectra of stars and his discovery of *Nova Lacertæ.—The Observatory.*

Periodic comets due to return to perihelion in the present year include Holmes's Comet, period 6.86 years: Finlay's Comet, period about 6½ years; Kopff's Comet (1906 IV), period 6.67 years. These belong to *Jupiter's* comet family. The first named was so exceedingly faint at its last return, in 1906, that it is very doubtful whether it will be seen again. The chances for the detection of Finlay's Comet are rather better. The orbit of Kopff's Comet must be regarded as somewhat uncertain, as it has been observed at one apparition only. In addition to these, the only periodic comet whose return can be hoped for during the year is Westphal's Second Comet, discovered on June 27, 1852. If the period of about sixty years is correct, this object should now be approaching the Sun. Search ephemerides for this comet are given by M. A. HNATEK in *Astronomische Nachrichten,* **193**, 205, 1912, and for Finlay's Comet by M. G. FAYET in *Astronomische Nachrichten,* **193,** 333, 1913.

M. B. BAILLAUD, director of the Paris Observatory, has been elected president, and M. H. DESLANDRES, director of the Meudon Observatory, vice-president, of the Paris Bureau des Longitudes for 1913.

Sir DAVID GILL has been elected the first honorary member of the Astronomical and Astrophysical Society of America.

OFFICERS OF THE SOCIETY

Mr. Alex. G. McAdie	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. R. T. Crawford	*Second Vice-President*
Mr. J. Costa	*Third Vice-President*
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The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the Chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

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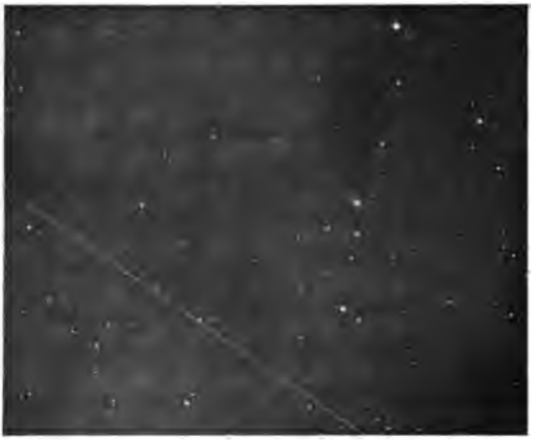
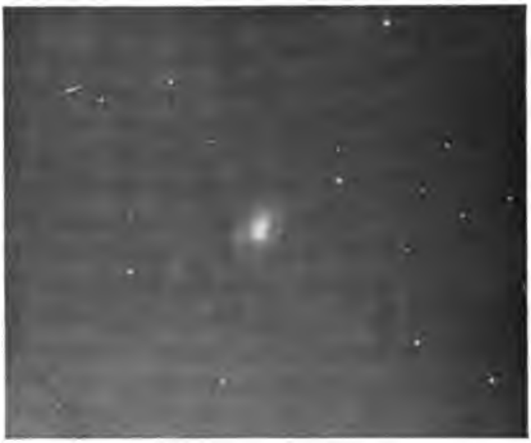


THE SMALL SPIRAL NEBULA N. G. C. 7457 AND METEOR TRAIL.
Crossley reflector, September 11, 1912; exposure two hours.



THE SPIRAL NEBULA N. G. C. 3368 AND TRAIL OF THE ASTEROID SIWA.
Crossley reflector, April 9, 1913; exposure two hours.

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THE IRON SPECTRUM.

By Keivin Burns.[1]

The astronomer has a twofold interest in the spectrum of iron. In the first place, a large percentage of the lines which have been identified in the spectra of celestial bodies are due to this element. Not only has it been discovered in the Sun and in many of the stars, but the behavior of the iron lines has told us much concerning the conditions which exist in these bodies. The progressive changes in the relative intensities of the iron lines is one of the indications of progression in spectral type. Together with those of other elements, the iron lines are leading us to understand the phenomena which are observed in sun-spots, in the chromosphere and in other parts of that star in which we are most interested. Through the effect of pressure on wave-length, we are able to form rather an accurate estimate of the pressure which exists in the reversing layer; by means of the Doppler effect we can study the circulation in the Sun, and by means of the Zeeman effect Professor Hale has found it possible to observe the magnetic and hence also the electric conditions existing in sun-spots and elsewhere on the solar surface. In all these investigations we are more or less concerned with the iron spectrum, either directly or indirectly.

For, aside from the interest attaching to the iron lines themselves, there is the fact that iron has long been used to furnish the standards with which the spectra of terrestrial or celestial sources are compared. Much of our knowledge of the radial velocities of the stars rests on measurements of the iron spectrum, either as terrestrial standards or as lines in the stars themselves. Hence the great amount of labor which has been spent in determining accurate values for the wave-lengths of the iron lines.

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[1] Mr. Burns has held the Martin Kellogg Fellowship of the Lick Observatory during the academic years 1911-1913. He spent the major portion of the year 1911-[illegible] at the University of Bonn, his principal work being the investigation of the spectrum of iron under the direction of Professor Kayser. He is at present at Marseilles continuing his research work in the laboratory of MM. Fabry and [illegible]

Quite recently the International Solar Union made a series of recommendations looking to the determination of a new system of wave-lengths having an accuracy sufficient for all present-day purposes. The wave-length of the red cadmium line, as determined by BENOÎT, and FABRY and PEROT, was chosen as the basis of this system. The absolute wave-length of this line was determined by counting the number of times its length is contained in that of the standard meter. This count was made by the ingenious method devised by MICHELSON, and when one realizes that it takes nearly two million waves of this length to make a meter, it becomes evident that this fundamental step in spectroscopic metrology tests the observer's fortitude and skill. Now that this wave-length has been so determined, if some calamity should cause the Paris meter to disappear, it could be replaced with an accuracy of one ten-millionth of its length, by comparing a new standard with the wave-length of the red cadmium line. In other words, the error in the wave-length of the cadmium line is not greater than one twenty-billionth of a millimeter, a quantity much beyond our imagination.

The second step in the Union's program is the determination of secondary standards by the interference method at intervals of 50 A (A = Ångstrom = $1 \times 10^{-7\text{mm}}$). The third step is the interpolation of tertiary standards at intervals of 10A by means of measures made with gratings. The iron spectrum was chosen to furnish these secondary and tertiary standards because suitable lines are found in it throughout the greater part of the region of wave-lengths which can be readily photographed. This region extends at present from about 2000 A to 9000 A. By means of Schumann plates it is possible to photograph, in vacuo, wave-lengths as short as 1000 A; and by means of dyed plates and very long exposures 10,000 A can be reached. By the phosphorescence method, 15,000 A can be photographed, but no known means enables us to photograph interference rings of wave-length longer than 9000 A without resorting to impossibly long exposures. The astronomer's direct interest in spectra stops rather abruptly at 2900 A, at which point our upper atmosphere becomes opaque.

While his interest in spectra stops on the side of shorter wave-lengths at a point where the ordinary photographic plate is still sensitive, the astronomer, and also the meteorologist, is greatly concerned in the improvement of plates sensitive to the longer wave-lengths. Each of the last four decades has witnessed the introduction of better methods of photographing light to which ordinary plates are not sensitive; still it seems probable that a systematic study of the subject, by a few persons devoting all their energy to the undertaking, might accomplish as much in one year as has been accomplished in this line in the last twenty. The production of special emulsions sensitive to the infra red is receiving little attention, and no one seems to be experimenting with other emulsions than those containing a haloid of silver. No doubt plates could be made which would be at least as sensitive as those of Captain ABNEY, which no one else has as yet succeeded in making, and these might be greatly improved by the addition of a dye. A systematic search for better dyes promises very well, and this phase of the subject is receiving some attention, though not so much as it deserves. It has long been known that certain alkalies affect the sensitiveness of plates. For instance, the use of ammonia with dicyanin makes the stained plate more sensitive than one bathed with dicyanin alone, and the increase in sensitiveness is most marked in the infra red. It may be that some other chemical can be found which will prove to be better than ammonia as a stimulant to stained plates. The makers of commercial plates have only recently begun to take a great interest in red sensitive plates. It is to be hoped that color photography will stimulate the search for plates more sensitive to red light. The growing use of the neon tube as a means of illumination may also increase the demand for such plates, and plates which are very sensitive to red are likely to be somewhat sensitive to the infra red.

The work of determining secondary standards was undertaken by BUISSON and FABRY at Marseille, by EVERSHEIM at

Bonn, and by PFUND at Baltimore. The wave-lengths of lines which are to be used as standards are compared with that of the red cadmium line by the method of PEROT and FABRY. The chief feature of this method consists in measuring the diameters of the rings formed by interference when light is passed through two plane parallel plates. The plates are lightly silvered, to give the rings greater brightness. The three series of measurements mentioned above have been published for the region 4282 A – 6494 A. In part of this region the standards are farther apart than is desirable, and in the yellow-green they are lacking. BUISSON and FABRY have measured standards as far as 2373 A on the side of shorter wave-lengths, and EVERSHEIM has reached 6941 A at the other end of the spectrum. The writer has recently measured a number of lines between the limits 5434 A and 6678A. The lines in the yellow are all rather broad and unsatisfactory; many of the lines measured are fainter than standards should be, but very useful in the reduction of measures on the iron spectrum itself. In spite of the rather unsatisfactory nature of these lines, the writer considers iron better than barium or any other element which has so far been suggested for this region. The last-mentioned series is being extended to 8668 A, and one rather faint line can be measured at 8824 A. There are places between 6700 A and 8668 A where the iron spectrum does not have lines close enough together to comply with the recommendations of the Solar Union. However, this region cannot be observed with so great a dispersion nor with such accuracy as the region of half the wave-length, so we may be satisfied with those standards which can be furnished by iron.

The third step in the Solar Union's program is the determination of the tertiary standards at intervals of not more than 10 A. The Union recommended the use of large concave gratings for this step, but the work has so far largely been done by means of plane gratings. The latter gives a spectrum which is nearly linear and the former gives one which is practically normal; in either case it is extremely simple to determine the wave-lengths of other lines by interpolating between the secondary standards. The accuracy of values so determined is not very far behind that of the secondary standards themselves:

still the writer favors the determination of all standards by the interference method. Mr. St. John has taken up the work of measuring tertiary standards and he has published the wave-lengths of a number of iron lines in the region 5371 A – 6494 A, together with an estimate of their fitness to serve as standards. Dr. Goos has published measures of the stronger iron lines in the region 4282 A – 6494 A. Dr. Geiger has measured the red and infra red iron spectrum with moderate dispersion. His last line is 9809 A, but only four lines of wave-length greater than 9000 A were found. Dr. Geiger did not use the international system. Some three thousand lines in the arc spectrum of iron were recently measured by the writer at Bonn by means of a twenty-one-foot concave grating. The measures extend from 2373 A to 8824 A. By comparing the values obtained by different observers it appears that sharp lines can be measured with an accuracy of two or three thousandths Angstrom. Whether or not spectroscopists will be satisfied with this degree of accuracy in their standards, it is at least certain that the measurements of the last few years will suffice to identify the iron lines wherever they may be found.

We might contemplate human ingenuity with a good deal of complacency when we consider that thousands of values can be measured to one five billionth of a millimeter. But if we look further we see that this uncertainty in wave-length corresponds to an uncertainty in the number of vibrations per second amounting to nearly ten billion, which shows us that there is still much room for improvement in our metrology. In other words, an error of three thousandths of an Angstrom in the case of visible wave-length means an error in the number of vibrations per second which is over half a million times as great as the whole range of vibration frequency to which the human ear is sensitive.

In Mr. St. John's work, cited, above, he examined the lines particularly with reference to pressure effect and it is his opinion that lines which are greatly displaced by this effect should not be used as standards. This investigator found several lines which are displaced in a measurable degree by a difference of pressure of one fifth of an atmosphere, the differenc between the density of the air at Pasadena and at Mount Wilson.

Dr. Goos made a study of the discrepancies which arise between different series of accurate measurements and in the course of this investigation he found the wave-lengths of some lines to depend on the part of the arc which served as source. By means of exposures made with a short arc as source and others for which the center of a long arc was used as source, Dr. Goos found that several lines, particularly in the green and yellow, have wave-lengths which are different near the electrodes from what they are in the center of a long arc. He finds the wave-lengths of such lines to be dependent on the conditions under which the arc burns, such as voltage, amperage, size of electrodes and their separation; and he points out that before such lines can be used as standards it will be necessary to determine minutely the conditions under which they are to be observed. In the series of measures made at Bonn it was found that the ordinary arc lines frequently have close companions in the spectra of the electrodes. There are scores of cases to be found in the ultra violet where a line which is single in the center of the arc has a companion, perhaps stronger than itself, in the electrode, the separation being two or three hundredths Ångstrom. Observations have frequently differed because one observer measured the mean of two lines and another measured only one of them. In this case the former is a measure of the electrode spectrum, the resolution being too small to separate the pair, and the latter is a measure of the spectrum of the center of the arc. This phenomenon may explain some of the shifts found by Dr. Goos. In the green and yellow the lines are not so sharp as in the ultra violet, and it is not possible to distinguish between a close companion and an unsymmetrical broadening. For investigating such cases, it is of great advantage to have no astigmatism in the spectrograph. In the green of the second order of a concave grating, the light from all parts of the arc is pretty well mixed by the astigmatism.

Of the lines measured in the iron spectrum at Bonn, about a hundred are due to impurities. Manganese, nickel and chromium furnish most of these; cobalt, calcium and copper are represented by a few lines each. An examination of the relative intensities of these lines shows that the spectrum of an impurity in the iron arc resembles the spark spectrum of the element very closely. In this connection we recall that M. DE GRAMONT has found that the smallest trace of an impurity which will make itself known in the spectrum of another element always shows the same lines, regardless of whether the source be a hot flame, the arc, or the spark. These "last lines" in the case of some metals are enhanced lines. M. DE GRAMONT finds that these last lines are prominent in the spectrum of the chromosphere and present in the spectra of stars which have few metallic lines, viz., stars of Class B5 to A5. This would tend to show that the elements in question are present in rather small quantity, and there are other reasons for believing that this is the case. For the absorption is usually rather weak in the case of the metallic lines in the spectra of stars of early type; in the case of the chromosphere this region lies high above the level of the dense metallic layer which gives the absorption spectrum. In stellar spectra showing few metallic lines the relative intensities are more nearly those of the spark than those of the arc. This phenomenon has been explained by the assumption that these stars are hotter than those of Classes F and G, it being held that the spark is a hotter source than the arc. This theory that the spark is hotter than the arc is not borne out by the discovery by BUISSON and FABRY that the spark spectrum is produced in the arc at the tips of metallic electrodes. Neither this theory nor the one attributing the characteristics of the spark spectrum to the suddenness of potential drop is strengthened by the fact that a trace of manganese gives the spark spectrum of this element in the center of the iron arc. There is always very much less incandescent material in the spark than in the arc and this condition may play an important role in determining the relative intensities of the resulting spectral lines. In any case the results of M. DE GRAMONT and the behavior of impurities in the iron arc leads us to suspect that the quantities of the elements present may be more influential than is the temperature in determining the kind of spectrum a star will show. This consideration should stimulate, if any stimulus were necessary, the study of the spectra of mixed gases, and the study of the spectra of metals in various atmospheres.

ABSTRACTS OF PAPERS READ AT THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY, BERKELEY, CAL., ON FRIDAY, APRIL 11, 1913.

Among the papers presented at the April 11th meeting of the Society were eight by advanced students of astronomy in the Lick Observatory and the Students' Observatory at Berkeley. Six of these students—Miss WATERMAN and Miss GLANCY, and Messrs. MERRILL, KIESS, EINARSSON and HAYNES — received the degree of Doctor of Philosophy from the University of California on May 14, 1913. Their papers were the theses they presented in partial fulfillment of the requirements for this degree. Miss KIDDER's paper was the thesis presented for the degree of M. A., and Mr. LANZENDORF's the thesis presented for the degree of B. S., awarded at the same commencement. The theses for the doctorate, mentioned above, will be published later in other journals. Abstracts of the eight papers are printed here.

CLASS B STARS WHOSE SPECTRA CONTAIN BRIGHT HYDROGEN LINES.

By PAUL W. MERRILL,
Fellow in the Lick Observatory, 1910-1913.

The normal or typical stars of Class B show only absorption lines, the characteristic lines being those of helium and hydrogen. There are known, however, nearly seventy that have bright hydrogen lines. The brightest of them, γ *Cassiopeiæ,* was discovered visually by SECCHI in 1866. Most of the other stars have been found photographically by the Harvard College Observatory. Hβ was the bright ray most frequently detected. Ordinary photographic plates are not sensitive to red light, so it remained for CAMPBELL, observing visually with the 36-inch refractor in 1894-5, to find that when Hβ is bright Hα is also bright and stronger. Both bright and dark hydrogen lines exist in these stars. CAMPBELL formulated the following rules concerning them, which are confirmed by my observations:—

(a) Some stars contain both bright and dark hydrogen lines.

(b) The bright lines in such stars are those of greater wave-length, the dark lines are those of shorter wave-length.

(c) The intensities of the bright lines decrease as we approach the violet.

(d) The intensities of the dark lines increase as we approach the violet.

What actually occurs in most cases is the overlapping of the bright and dark series of lines, each agreeing with rules (c) and (d) respectively. Thus, for instance, we often find Hβ and Hγ complex, consisting of both bright and dark lines, Hα bright without visible absorption, Hδ and succeeding hydrogen lines dark with bright parts very faint if visible at all.

Bright helium lines are also present in a very few of these stars, and a few other bright lines have been noted.

The study of this group of stars made by the writer is largely based on a series of photographs of the red region of their spectra. Hα of γ *Cassiopeiæ* was photographed in the second order of a 15,000-line plane grating.

Four new stars of Class B were found to have bright lines, one case having been previously suspected by Miss CANNON. Two of them are *Pleiades* stars, making in all four of that interesting group to show bright lines. One of them, *Pleione*, seems to have recently lost its bright rays. The bright-line stars have a tendency to gather in small groups, i. e. several are often found close together in the sky. In general, the only peculiarities of their distribution are those common to the whole of Class B. A count according to magnitude apparently shows that the brighter stars of Class B have bright lines more frequently than the fainter ones. We may take this to mean that a large star, of great intrinsic luminosity and having intense conditions in its atmosphere, is more apt to emit bright-line radiations than a smaller, weaker star.

In no case are the bright hydrogen lines monochromatic, but are broad or double. This duplicity has been previously noted in a few instances, but my observations show it to be of common occurrence. A large number of the lines are double and the appearance of the remaining ones is such that it seems probable that all are really double, though not always detected because observed with insufficient dispersion, or because the components are broad and hazy and run together. Hα is seldom seen double, doubtless due to the causes just mentioned. In ε *Capricorni* the components of Hα stand clearly apart, with a separation of seven Ångstroms. The grating spectrograms of γ *Cassiopeiæ* give an intensity curve for Hα that probably indicates two blended components, their centers being about three Ångstroms apart. Of the other hydrogen lines the average separations are:

Bβ	(21 stars)	3.5 Ångstroms
Hγ	(8 ")	2.6 "
Hδ	(2 ")	2.2 "

In the individual stars there are large variations from these numbers and from their ratios. There seem to be no consistent relations such as those of Doppler or Zeeman effect.

The components of the bright lines do not unite as they would if due to a pair of revolving bodies, within any period of the order of length of the periods of spectroscopic binaries of Class B. They stand apart for months and years, and apparently permanently, at about the same separation.

The bright components of Hβ, of b^2 *Cygni*, and γ *Cassiopeiæ* were tested for polarization. The results were in general negative, i. e. no large proportion of the light is polarized. However, one plate of each star gave slight indications of plane polarization of the outside edges of the double lines.

Complex self-reversal, similar to the self-reversal of the electric arc, is favored as an explanation for the observed lines. There is the negative argument that no other explanation seems at all satisfactory. The positive evidence may be briefly stated as follows:—

The appearance of many of the lines suggests self-reversal;

The separations of the bright portions are about what one might expect under this hypothesis;

The bright lines occur in stars with hot extensive atmospheres, and probably more often in stars larger than the average;

There are qualitatively similar reversals in the Sun.

D, of γ *Cassiopeiæ* appears on my plates as a very faint bright line. To be seen visually, as it has been in the past, it would have to be considerably stronger. In about a dozen stars several enhanced metallic lines show bright. φ *Persei* is the best example found. The lines of this star correspond closely to the strongest lines of the solar chromosphere, with the exception of the lines of magnesium, sodium, and helium. The lines of sodium and helium are dark in φ *Persei*, and magnesium is not represented at all. Many of the bright lines are double. That the lines of the atmosphere of a solar star should be present in the spectra of Class B stars argues for the unity of the stellar system.

In order to trace evolutionary relationships we should have an extensive series of observations of stars beginning with the Wolf-Rayet type and extending through the late subdivisions of Class O up to Class B; and, again, observations of numerous objects of Classes A and F, since there are stars classified from Bo to Fo which have bright lines.

THE CLUSTER VARIABLE RR *LYRÆ*.

By C. C. Kiess,
Fellow in the Lick Observatory, 1910-1913.

In a previous article, appearing in this journal for August, 1912, the writer has attempted to give an account of the general features and characteristics of the cluster variables, and also some theories which have been put forth in explanation of this peculiar type of variation. Of the isolated cluster variables, the brightest one so far as known is RR *Lyræ*, which at maximum is of magnitude 7.0 and at minimum of magnitude 7.8. This star has been observed both photometrically and spectrographically at the Lick Observatory during the summer and autumn months of 1912. Credit is due to Dr. S. D. Townley for making a number of the earlier photometric observations. All the other observations of the star, photometric and spectroscopic, were made by the writer.

The light curve derived from the Lick observations differs but slightly from that based on the observations made by Wen-

DELL at Harvard and confirms the conclusion that RR *Lyræ* belongs to the cluster variables. At minimum the light is practically constant for approximately one third of the period. The rise from minimum to maximum is extremely rapid. A comparison of the times of maximum as observed at the Lick Observatory with the first epoch of maximum observed by WENDELL, resulted in a new period of 0.566826 day. In a letter to Director CAMPBELL, HERTZSPRUNG of Potsdam stated that he had observed a *photographic* maximum of RR *Lyræ* on J. D. 2418919.448 Gr. M. T. A comparison of this date with the dates of visual maximum resulting from both the Harvard and Lick observations revealed the remarkable circumstance that in the case of RR *Lyræ* the maximum intensity of the photographic rays occurs 2.7 hours before the maximum intensity of the visual rays. A new epoch of visual maximum is J. D. 2419697.764.

The spectrographic observations were made with the one-prism instrument attached to the 36-inch refractor. Measurement of the spectrograms showed a variable velocity in the line of sight, the period of velocity variation being coincident with the light period. The variable is therefore a spectroscopic binary. Its orbital elements were derived by the method of LEHMANN-FILHÉS and later corrected on the basis of a least-square solution.

RR *Lyræ* possesses the characteristic that is so pre-eminently a distinguishing feature of the *Cepheid-Geminid* variables—namely, that maximum light occurs at the time of maximum velocity of approach toward the observer. Hence, there can be little doubt but that the light variations of the bright star are due, directly or indirectly, to the influence of the less brilliant member of the system. That eclipses are in no way responsible for the observed light variations is evidenced by the relations existing between the light and velocity curves. We may conclude, therefore, that in so far as the observed features of RR *Lyræ* are characteristic of the group, the cluster variables are but extreme types of the family of variables of which the *Cepheids* and *Geminids* are members.

The most plausible theory advanced in explanation of short-period variation is the variation-in-absorption theory due to

DUNCAN. Although this theory offers an explanation of the synchronism between light maximum and velocity minimum, yet in the case of RR *Lyræ* it fails to account for the discrepancy that exists between the times of visual and photographic maxima. Consequently, we conclude that before a satisfactory theory can be formulated additional knowledge is required as to the nature of the light variations of the short-period variables as observed in light of different wave-lengths.

April, 1913.

THE VISUAL REGION OF SPECTRUM OF BRIGHTER CLASS A STARS.

By E. PHŒBE WATERMAN,
Vassar College Fellow in the Lick Observatory, 1912-1913.

Plates of 132 Class A stars were secured with the one-prism spectrographs in regular use with the 36-inch refractor, covering, in two sections, the region K to Hβ. The plates used were Seed 23, stained for the visual region with WALLACE's three-dye solution. The lines present in the visual region of each spectrum were identified by comparison with the spectrum of α *Cygni*, in the Hartmann spectrocomparator, and the wave-length of each line obtained by measuring and reducing (by the Hartmann formula) several spectrograms of this star. Lines which were not found in its spectrum and which appeared in spectra of sub-class A5, were identified from neighboring α *Cygni* lines and the wave-lengths obtained by measurments of A5 spectra with sharp lines.

The results secured were briefly:—

(1) The lines in the visual region agree in general appearance, in source, and in intensity, with those of the photographic region. The contrast with the continuous spectrum is slight, however, and the lines much more difficult to obtain than in the photographic region, so that the criteria afforded by the visual region seem too few to make this part of the spectrum essential in classification work. The *b* group of magnesium shows steady development from sub-class to sub-class, and is of value for classification purposes; the D lines are exceedingly

erratic and not to be depended upon, being present as fine sharp absorption lines in some Class B stars, and appearing only as a faint and hazy blend in some A5 stars.

(2) The lines present in the visual region are the enhanced lines of the metals represented, and include all the stronger lines of the solar chromosphere. Some metals come to an apparent maximum in A2; most metallic lines increase steadily in strength from A0 to A8.

(3) The metals show considerable range in intensity within the limits of each sub-class, a development independent of K. This is one cause of the differences to be found among spectra classified as alike on the basis of K and the hydrogen lines.

(4) A comparison of slit and objective-prism plates (based upon nine stars whose spectra, with the slit spectrograph, showed metal lines unduly strong for the class assigned) shows that the faint lines are finer, more clearly defined, and contrasted more sharply with the continuous spectrum in the slit spectrograms than in the objective-prism plates. Differences between individual lines and between spectra appear in the former which are not striking in the latter. This is a second possible cause of discrepancy among Class A stars.

(5) A count of the stars of the Revised Harvard Photometry by sub-classes shows that for all except Class B, more stars are included in sub-class 0 than in sub-classes 1-4 or 5-6, inclusive, and that in classes A and K respectively the 0 sub-class comprises as many as three and seven times the total number of stars in the rest of the class.

One possible, and easy remedy for the discrepancies among Class A spectra is (1), to adopt Miss CANNON's suggestion as to shifting the sub-classes, making A3 into A5 and A5 into A8, and leaving A0 to A2 for stars now classified as A0; (2) to subdivide these groups on the basis of the metal lines, adopting some system such as is used in libraries for the classification of books, which is capable of indefinite extension and subdivision.

April, 1913.

ON V. ZEIPEL'S THEORY OF THE PERTURBATIONS OF MINOR PLANETS OF THE *HECUBA* GROUP.

By A. Estelle Glancy,
Fellow in the Lick Observatory, 1908-1910; Watson Assistant in Astronomy, Students' Observatory, 1910-1913.

By reason of the difficulties encountered in determining the perturbations of certain minor planets, and in recognition of a practical analytical treatment by groups, we adopt a natural and useful classification according to their common characteristic. This common characteristic is the near commensurability of the planets' mean motion with that of the primary disturbing body, *Jupiter*.

Let *Jupiter's* mean daily motion be n', that of the planet n. Whenever the ratio

$$\mu = \frac{n'}{n}$$

is approximately the ratio of two low integers, practical difficulties arise.

Now *Jupiter's* mean motion is 299″, and the planets of the group to which *Hecuba* belongs have mean motions near 600″. The ratio is, therefore,

$$\mu = \tfrac{1}{2}.$$

Ordinarily, the perturbations are expressed in trigonometric series, according to ascending powers of the disturbing mass. But for these planets, which Gyldén appropriately calls characteristic planets, the series converge very slowly, if they do not actually diverge. Such expansions are, therefore, to be avoided.

For ordinary planets we employ the method of Hansen, in which the expansions are of this type. It is easy to see that for near commensurability Hansen's integrations become indeterminate.

The differential equations of the second order contain trigonometric series of the form—

$$a \genfrac{}{}{0pt}{}{\sin}{\cos} (i\,n - i'\,n')\,t$$

where i and i' are integers, and

$$-\infty < i < +\infty \qquad 0 < i' < +\infty$$

The integral with respect to the time is of the form—

$$\frac{a}{(i n - i' n')^2} \begin{matrix} \sin \\ \cos \end{matrix} (i n - i' n') t$$

If n and n' are nearly commensurable, there will be some values of i and i' for which the denominator of the coefficient is nearly zero. For instance, for the *Hecuba* group—

$$i = 1$$
$$i' = 2,$$

gives an infinite integrating factor, for exact commensurability.

In order to solve the problem for characteristic planets, Bohlin adapted the method of Hansen to the case of nearly commensurable mean motions, by the use of the exponential. Evidently, if, in place of sines and cosines, we introduce the exponential through the relation—

$$e^{i\theta} = \cos \theta + i \sin \theta,$$

where

$$\theta = (i n - i' n') t,$$

the indeterminateness for the case

$$i n - i' n' = 0.$$

is removed.

Bohlin retained the fundamental principles of Hansen and his differential equations; the departure from Hansen consists in the form of integration. The method appeared in 1896,[1] and was later extended in a French edition.[2]. In addition to the analytical developments, he published preliminary tables which are common to all groups of planets and also those which apply to the particular group $\mu = 1/3$.

H. v. Zeipel has taken up the *Hecuba* group according to the theory of Bohlin, performing the integrations in essentially the same manner, but employing his own formulæ, and adding to Bohlin's work his own determination of the constants of integration.[3]

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[1] "Formeln und Tafeln zur gruppenweisen Berechnung der allgemeinen Störungen benachbarter Planeten," *Nova Acta Reg. Soc. Sc. Upsaliensis*, Ser. III, Band XVII, 1896.

[2] "Sur le Développement des Perturbations Planétaires," *Application aux Petites Planetes*, Stockholm, 1902.

[3] Angenäherte Jupiterstörungen für die Hecuba-Gruppe," St. Petersburg, 1902.

The differential equations of HANSEN are:—

$$(1)\quad \frac{dW}{d\epsilon} = M a_1 \frac{\delta\Omega}{d\epsilon} + N a_1 \bar{r} \frac{\delta\Omega}{\delta\bar{r}}$$

$$(2)\quad \frac{dn\delta z}{d\epsilon} = (1 - e\cos\epsilon)\frac{W + \nu^2}{1 + W}$$

$$(3)\quad \frac{d\nu}{d\epsilon} = -\tfrac{1}{2}\,\frac{(1 - \nu^2)}{1 + W}\,\frac{\delta W}{\delta\Psi}$$

$$(4)\quad \sec i\,\frac{dU}{d\epsilon} = Q a^2\,\frac{\delta\Omega}{\delta z}$$

It is evident that the function W is very important and must first be obtained by integration of (1). The integration of (2), (3), (4) gives the three components of the planet's displacement due to the action of *Jupiter.*

These functions may be expressed in trigonometric series, in which the argument is of the form—

$$a\epsilon + b\theta + c\Delta + d\Sigma,$$

where ϵ is a disturbed eccentric anomaly, Δ and Σ are constants depending upon the elements π and Ω, and θ is defined through the relation—

$$\theta = \tfrac{1}{2}\,(\epsilon - e\sin\epsilon) - g',$$

to be determined from a differential equation—

$$\frac{d\theta}{d\epsilon} = f\,(W)$$

The eccentricities and mutual inclination of the planet's orbit and *Jupiter's* orbit appear explicitly as factors of the coefficients.

The series are ordered according to ascending forms of a small quantity w, defined by the relation—

$$\mu = \mu_0\,(1 - w)$$

$$\mu = \frac{n'}{n}$$

$$\mu_0 = \tfrac{1}{2}$$

Since these series are functions of μ, they may be written in terms of μ_0 and w.

$$f(\mu) = f(\mu_0) + f_1(\mu_0)\, w + f_2(\mu_0)\, w^2 + \dots$$

The possibility of developing the perturbations in such a TAYLOR's series, upon the basis of exact commensurability, is the underlying principle of the group method.

Two important facts are to be noticed: First, that the elements appear explicitly in Δ, Σ, n, g^2, and w. In the method of HANSEN they are contained implicitly in the coefficients. Secondly, the argument θ contains implicitly the perturbations which are to be determined.

The developments proceed according to positive powers of m', and according to both positive and negative powers of w. Hence, if w is small, terms containing negative powers are numerically of lower order than is indicated by the mass factor. In place of the mass factor as the unit of order, the factor $\frac{m'}{w}$ is used. Assuming that w and $\sqrt{m'}$ are of the same order, we define successive ranks as follows:—

Rank				
0	1	$\frac{m'}{w^2}$	$\frac{m'^2}{w^4}$	. . .
1	w	$\frac{m'}{w}$	$\frac{m'^2}{w^3}$	. . .
2	w^2	m'	$\frac{m'^2}{w^2}$	. . .
.	.	.	.	

In general, the mass factor is absorbed in the numerical coefficients and the tables have the following form:—

Sine Cosine	$n^p n^q g^{2r}$	w^s
Δ		
$2\theta + \Delta$		
$\epsilon + 2\theta + \Delta$		
$\epsilon + 4\theta + 3\Delta - \Sigma$		

Where, in general, there are three columns of coefficients, e. g. s has three values corresponding to the first three terms of the Taylor series.

In these tables the arguments are functions of both ϵ and θ. Therefore to accomplish the integration we write, for instance,

$$W = f(\theta, \epsilon)$$

$$\frac{dW}{d\epsilon} = \frac{\delta W}{\delta\epsilon} + \frac{\delta W}{\delta\theta}\,\frac{d\theta}{d\epsilon}$$

in which $\frac{dW}{d\epsilon}$ is known. The integration is then accomplished by the solution of partial differential equations in—

$$\frac{\delta W}{\delta\epsilon} \text{ and } \frac{\delta W}{\delta\theta}$$

With this purpose in view, the functions are segregated in two parts, one which always contains ϵ explicitly and one which is independent of ϵ explicitly, the latter being indicated by square brackets. For instance—

$$W = (W - [W]) + [W].$$

With these general principles, it is possible to integrate rank by rank, and the function is finally given by the sum of the integrals.

The solution of these differential equations includes the determination of constants of integration. Since the method is based upon the fundamental principles of HANSEN and the initial elements are osculating elements, these constants must be determined to satisfy the condition that the perturbations and their velocities are zero at the date of osculation. Recalling the fact that co-ordinates and their velocities for a given time determine osculating elements, it is clear, by analogy, that $n\delta z$, ν and $\frac{u}{\cos i}$ and their velocities at $t = 0$, can be absorbed in the elements.

Given osculating elements and tables for the group ½, the computer first determines this set of constant elements, which may be described as the osculating elements modified by the constants of integration. Having these elements and perturbations taken from tables, the process of computing the disturbed position is exactly the same as in HANSEN's method.

The residuals $(o - c)$, obtained in this manner for a sufficiently large number of oppositions, serve for a correction of elements.

Concerning a practical application of the method, the following general remarks are of interest:—

First, the perturbations are large. In the case of (10) *Hygiea* $n\delta z$ reaches the magnitude of 5°. Since the argument of the perturbations is a function of the disturbed position, a second approximation for $n\delta z$ is generally necessary.

Secondly, the computation, inclusive of second order in the mass, second degree (and occasionally third degree) in the eccentricities and inclinations, is quite long.

Thirdly, too much emphasis cannot be placed upon good initial elements.

Again, a successful correction of the elements is difficult. Although second order terms in the mass are included, second degree in the eccentricities and inclinations (a few of third degree), and the first three terms in the TAYLOR's expansion in w, the residuals for a large number of oppositions show an irregularity of wider range than is desirable. To take up this irregularity which may be due to some omitted terms arising from the action of *Jupiter*, or to perturbations by *Saturn*, *Mars*, or the Earth, all of which have mean motions nearly commensurable with the *Hecuba* group, it is essential that the observations used for a correction of elements shall be well distributed around the orbit.

With these general considerations in mind, the tables of v. ZEIPEL are considered applicable to planets of the *Hecuba* group, within the following limits:—

$$\phi = 10^\circ$$
$$i = 10^\circ$$
$$550'' < n < 650''$$

BERKELEY ASTRONOMICAL DEPARTMENT,
UNIVERSITY OF CALIFORNIA,
1913, April.

THE MINOR PLANETS OF THE *TROJAN* GROUP.

By Sturla Einarsson,
Instructor in Astronomy, University of California.

The dates of discovery and approximate mean motions of the four minor planets belonging to this group are as follows:—

Name.	Year of Discovery.	Mean Daily Motion.
(588) *Achilles*	1906	295″.5
(617) *Patroclus*	1906	300 .5
(624) *Hector*	1907	293 .1
(659) *Nestor*	1908	300 .8

The mean motion of the planet *Jupiter* is 299″.1, from which it will be seen that all five bodies travel about the Sun at approximately the same rate. The variation in the distance, asteroid-*Jupiter*, during one revolution is then primarily a function of the eccentricities. In the case of *Hector*, the eccentricity of which is 0.03, this distance is nearly constant. *Achilles* suffers the greatest variation in distance from *Jupiter*; but in no case does this greatly exceed 15 per cent. On this account, the perturbations due to *Jupiter* vary slowly. It is quite probable that the computation of *Jupiter's* disturbing influence may be avoided for one or more oppositions if its attraction is taken into account in the computation of the preliminary orbit. Owing to this near equality of mean motions, and smallness of eccentricity, the configuration, *Jupiter*-Sun-asteroid, remains practically unchanged during the revolution about the Sun. Three of these bodies are in the region 60° in advance of *Jupiter* as seen from the Sun, and one 60° behind. There may be departures as great as 15° to 20° from the equilateral triangle configuration. They nevertheless suggest Laplace's famous solution of this special case in the problem of three bodies.

Laplace proved that, given certain mass ratios and initial velocities, the equilateral triangle configuration would remain unchanged during the revolution of the system about its center of mass. As applied to our solar system, since the mass of the Sun is great as compared with the masses of the planets, this amounts to a revolution of the equilateral triangle about the vertex at which the Sun is situated.

According to the investigations of Professor E. W. Brown, the perturbations suffered by the *Trojan* group are of long period—probably 150 years. His researches show that the oscillations may be librational; that is, that the changes in the mean motion may be such as to carry the body from inside to outside (and *vice versa*) of the orbit of *Jupiter*. These oscillations may become large. In extreme cases the body may be carried from one triangle point to the other on the opposite side of the Sun from *Jupiter*. Brown has also been led to the interesting conclusion that this long-period variation in the mean motions is very nearly independent of the inclinations and eccentricities.

Definitive osculating orbits of these bodies will be of great assistance in the verification of these theoretical considerations. Only one has been computed to date, that of (624) *Hector*, by Professor Strömgren of the University of Copenhagen. The difficulties which he experienced and the great amount of numerical work which he had to perform, led to the investigation of the most suitable methods for the derivation of osculating orbits for the minor planets of this group.

Comparison of cometary orbits computed by many different methods has established the fact that the Laplacean methods yield, almost without exception, more accurate results and involve considerably less numerical work. In addition, when the attraction of a third body is appreciable, that method will yield the most accurate results which takes immediate account of this attraction in the computation of the preliminary orbit. Investigation of the orbits of (624) *Hector* and (588) *Achilles* was undertaken by Leuschner's method of deriving orbits on the basis of more than one attracting body in order to supply actual numerical verification of these statements.

It has been found in these two cases that an orbit based on the observations of one opposition, and computed by Leuschner's method of taking immediate account of the perturbations, will represent the observations of the preceding or following opposition, without further perturbations, within a minute of arc. The orbit of (624) *Hector* gave a better representation [illegible] after [illegible] was taken up first because it [illegible] between the [illegible] at the [illegible] Professor [illegible] elements of this asteroid. The [illegible] was taken up next. This is nearing [illegible] the writer to compute definitive [illegible] as well as to [illegible] in the case of all four asteroids [illegible] elements and the theoretical orbits [illegible]

[illegible]

[illegible]

[illegible]

only 4½ hours and a geocentric arc of 8′. The problem was rendered still more difficult by the smallness of the geocentric distance. Indeed, the equation in the geocentric distance resulting from a computation neglecting the parallax had no positive root. Very fortunately, however, Professor LEUSCHNER has recently developed a method for complete elimination of the parallax in orbit computations by Laplacean methods. The application of this method to the problem in question resulted directly in an orbit which represented all observations to within their probable relative uncertainties. This orbit, together with a search ephemeris, was published in *Lick Observatory Bulletin*, No. 210.

Using the ephemeris just mentioned, Mr. DAVIDSON discovered three undoubted images of the planet on plates secured at Greenwich on the night of October 11th with the 30-inch reflector. Since the discovery of these observations eight other images have been found at various places and announced as possible trails of *MT*. It was immediately realized that not all of these positions could be represented by any single orbit; but it was hoped that enough of them might prove consistent with the undoubted observations and with each other to justify the definite rejection of all others. Three of the eight observations come near realizing this condition, leaving outstanding relative discrepancies of about twenty or twenty-five seconds of arc. The errors of the photographic observations are certainly large, but probably not as large as this would require; moreover, this orbit is rendered doubtful by certain theoretical considerations. It, therefore, seems advisable not to reject offhand any of the eight observations, but to derive alternative solutions upon the basis of the undoubted observations and all others one at a time so as not to overlook any possibility of deriving the planet's real motion. This program is not yet complete, but it is hoped to have the discussion of all of the observations finished before the next favorable opposition by any of the resulting orbits.

A very unfavorable opposition of 1911 *MT* occurred some time early in the present year. The brightness was in the neighborhood of the twentieth magnitude. Dr. CURTIS of the Lick Observatory kindly offered to make a search for the planet with the Crossley reflector, and ephemerides based upon the most probable orbit were furnished him. During the course of his search he discovered three minute planets in the immediate neighborhood of the positions indicated by one of the ephemerides. Enough observations of all three were secured to render it certain that none were identical with 1911 *MT*. This failure to find the planet does not justify the rejection of the orbit upon which the search was based, because the predicted magnitude is very uncertain and the planet may have been in the region photographed, but too dim to be reached even by the Crossley. A more favorable opposition will occur in 1915 and it is hoped that the planet may be recovered at that time.

BERKELEY ASTRONOMICAL DEPARTMENT,
UNIVERSITY OF CALIFORNIA,
1913, April.

A COMPARISON OF PHOTOGRAPHIC WITH THEORETICAL POSITIONS OF MINOR PLANETS: (105) *ARTEMIS*, (115) *THYRA*, (119) *ALTHÆA*, (133) *CYRENE*, (139) *JUEWA*, (174) *PHÆDRA*.

BY ANNA R. KIDDER,
University Fellow in Astronomy, 1912-1913.

"By the will of JAMES C. WATSON, who died in 1880, a fund was bequeathed in trust to the National Academy of Sciences for the purpose of promoting astronomical research." Among other things, this was to include "the construction of tables of the minor planets discovered by the testator." In 1901, Professor LEUSCHNER was chosen to direct in person this work, which "was to embrace the numerical development of the perturbations, including terms only of the first order with respect to the mass of *Jupiter*, by HANSON's method; a correction of the elements by means of the differences between the computed and observed positions for all available oppositions; and the construction of tables to facilitate the computation of positions to the nearest minute of arc, from the date of discovery to 1930."[1]

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[1] Tables of minor planets discovered by JAMES C. WATSON: ARMIN O. LEUSCHNER, *Memoirs of the National Academy of Sciences*, Volume X.

In 1910 the first series of these tables were published in Volume X of the *Memoirs of the National Academy of Sciences.* It contains the tables of twelve of the twenty-two minor planets discovered by WATSON. The elements and perturbations in the case of each asteroid are based on oppositions extending from the date of discovery to about 1900, the latest opposition used in any case being that of 1904. It was therefore desirable that the accuracy of the tables be tested by comparison with observations at a much later opposition. Upon investigation, it was found that oppositions of six of these twelve asteroids occurred between September, 1912, and May, 1913, and a comparison between photographic and theoretical positions could thus be made.

The work as outlined included the computation of an ephemeris covering the date of opposition for each asteroid, based upon the tables already referred to; the observation of each asteroid with the photographic telescope at the Students' Observatory; the measurement and reduction of the plates; and a comparison of the photographic positions with those computed. Ephemeris positions of minor planets (105) *Artemis,* (174) *Phædra,* (133) *Cyrene,* (115) *Thyra,* and (139) *Juewa,* were thus computed, according to the directions and following the example given in Volume X of the *Memoirs of the National Academy of Sciences.* For these five asteroids, in opposition in 1912, a comparison between the ephemeris computed and the ephemeris published in the 1914 *Berliner Astronomisches Jahrbuch* could also be made. The 1915 *Jahrbuch,* which gives the opposition ephemeris of the sixth asteroid, (119) *Althæa,* has made use of LEUSCHNER'S tables, so that the computation of another ephemeris was unnecessary. All work was checked independently by Miss FLORENCE RYLE. By interpolation from the special tables for the planets the perturbations $n\delta z$, $\delta \log r = \log(1 + v')$, and $u/\cos i$, were formed, with the following result:—

PERTURBATIONS.

		$n\delta z$	$\log(1 + v)$	$u/\cos i$
(105) *Artemis*	Oct. 28.5	+0°.0116	—0.000218	—0°.0698
(174) *Phædra*	Nov. 27.5	—0 .3366	—0.000508	—0 .0293
(133) *Cyrene*	Dec. 07.5	+0 .8492	—0.001462	—0 .0200
(155) *Thyra*	Dec. 17.5	—0 .2287	—0.000589	—0 .0455
(139) *Jucwa*	Dec. 07.5	+1 .9104	—0.001544	+0 .0041

The comparison between the ephemeris positions computed on the basis of LEUSCHNER's elements and perturbations, and the ephemeris published in the 1914 *Berliner Astronomische Jahrbuch*, is shown in the following table. The table shows the comparison for only one date of each ephemeris, the residuals in α and δ being practically constant for all the dates of each ephemeris:—

	Date. Berlin M.T.	LEUSCHNER.		JAHRBUCH.		(B. J. — A. O. L.)	
		α	δ	α	δ	Δα	Δδ
		h m	° '	h m	° '	m	'
(105) *Artemis*	Oct 28.5	0 53.19	—2 10.8	0 55.3	—2 05	+2.1	+6
(174) *Phædra*	Nov. 27.5	4 50.81	+39 15.7	4 53.8	+39 20	+3.0	+4
(133) *Cyrene*	Dec. 07.5	5 28.73	+32 00.6	5 34.8	+32 00	+6.1	—1
(115) *Thyra*	Dec. 17.5	6 06.41	+38 08.1	6 09.5	+38 05	+3.1	+3
(139) *Juewa*	Dec 07.5	7 10.59	+39 27.2	7 03.5	+39 36	—7.1	+9

As already stated, no ephemeris was computed for (119) *Althæa*, LEUSCHNER's elements and perturbations being used in the computation of the ephemeris for the planet given in the 1915 *Berliner Jahrbuch*. The residuals in the above table indicate that in every case the position as given by the *Jahrbuch* is in error by an amount which might lead to wrong identification of planets.

To obtain the necessary observations for comparison with the computed positions, photographs were taken with the telescope belonging to the Students' Observatory. This telescope is a double combination of the portrait lenses of 5″.5 and 6″ aperture and about 22″ and 30″ focal length, respectively. Two or three photographs were taken for each asteroid except the first (105) *Artemis*, which it was impossible to get at the time of opposition on account of continuous cloudy weather. The lengths of exposures varied from an hour to an hour and a half, depending upon the magnitude of the asteroid and the atmospheric conditions. There being no micrometer attachment to the photographic telescope, the guiding was done by the slow-motion screws to keep the image of a star, chosen as near the center of the field as possible, upon the cross hairs of the eye-piece. Seed 30 dry plates were used and BARNARD's developer was used in developing them.

The planets (115) *Thyra*, (139) *Juewa*, and (119) *Althæa*, of magnitude 9.4, 10.3 and 9.0 respectively, were easily found in this manner. A careful search of the plates taken for (174) *Phædra* and (133) *Cyrene* was not successful, however. These planets were of magnitudes 12.4 and 12.0 and probably too faint to be found with the instrument used.

The photographic plates were then measured on the Repsold measuring engine. To simplify the measuring of the star plates, it was decided to take all readings from the horizontal scale of the instrument. The plate was to be first so orientated that the readings on the scale would give the x-coördinates directly; then after rotation through 90° in the proper direction, the scale readings would give y directly. Rotating again through 90° would give x reversed, and a third rotation y reversed. This plan was adopted for all plates.

To determine the scale value of the horizontal scale of the Repsold measuring engine, a ten-minute exposure of the *Pleiades* was taken. In spite of the fact that the plates taken with the smaller lens of the photographic telescope gave, in every case, better definition in all parts of the field, it was decided to use those taken with the larger lens, the advantage of larger scale being greater than the disadvantage of larger and less well-defined images. Two complete sets of readings for the seven brighter stars of the *Pleiades* were made from this plate. The right ascension and declination of those stars were taken from Boss's catalogue and transformed by JACOBY's[1] series and tables into rectangular coördinates. The mean of comparison between measured distances on the plate and the computed coördinates gave the scale value $1^{mm} = 259''.65$.

With a few simplifications suggested by PERRINE,[2] JACOBY's "Tables for the Reduction of Astronomical Photographs" were used in the reduction of the measured coördinates to intervals of right ascension and declination. Four or five catalogue stars situated as symmetrically as possible about the asteroid were chosen as comparison stars. To avoid corrections to the center of the plate, the mean of the known right ascensions and declinations, or in other words the center of gravity of the system of comparison stars, is chosen as plate-center; and the rectangular coördinates x and y of each star from the plate-center as origin, are computed by means of JACOBY's series.

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[1] Tables for the reduction of astronomical photographs: HAROLD JACOBY, "Contributions from the Observatory of Columbia University," No. 23.

[2] Preliminary note on "Some Simplifications in the Reductions of Stellar Photographs": C. D. PERRINE, *Lick Observatory Bulletin*, No. 102.

For the three asteroids for which photographic observations were not obtained at the Students' Observatory on account of cloudy weather and faintness of the asteroids themselves, a search was made among the published observations in the *Astronomische Nachrichten*. Photographic observations of (105) *Artemis* and (133) *Cyrene* from Heidelberg were found and these have been used in the comparison made. But for (174) *Phædra* no observation for this opposition has been found, and consequently no comparison for this planet can be made.

The photographs taken at the Students' Observatory gave the following positions of minor planets:—

			Gr. M. T.	Apparent Position.	
				α	δ
1	(115) *Thyra*	1912 Dec. 4	18h 30m.0	6h 22m.33	+ 39° 01′.6
2	" "	Dec. 5	18 50 .0	6 21 .21	+ 38 59.0
3	(139) *Juewa*	Dec. 31	17 59 .4	6 45 .45	+ 40 46.5
4	" "	1913 Jan. 2	18 18 .6	6 43 .00	+ 40 47.3
5	(119) *Althæa*	Feb. 27	18 44 .4	10 25 .20	+ 2 56.3
6	"	Mar. 2	19 12 .2	10 22 .64	+ 3 16.4

In the comparison use has also been made of the following observations published in recent numbers of the *Astronomische Nachrichten*:—

			M.Z.Kgst.	α	δ	
7	(105) *Artemis*	1912 Oct. 7	9h 06m.4	1h 09m.7	+ 2° 05′	*A.N.* 4607
8	"	Oct. 10	10 18 .0	1 07 .2	+ 1 24	*A.N.* 4609
9	" "	Oct. 12	11 18 .5	1 05 .3	+ 0 57	*A.N.* 4609
10	(133) *Cyrene*	Dec. 6	10 27 .8	5 30 .4	+ 32 01	*A.N.* 4621
11	(115) *Thyra*	Dec. 31	8 02 .9	5 49 .1	+ 36 20	*A.N.* 4625
12	(139) *Juewa*	Dec. 31	10 18 .9	6 45 .7	+ 40 46	*A.N.* 4625
13	(119) *Althæa*	1913 Feb. 25	11 13 .3	10 27 .2	+ 2 40	*A.N.* 4636

One visual observation made at the Students' Observatory by Mr. S. B. NICHOLSON is also available for comparison:—

			Gr.M.T.	α (app.)	δ (app.)
14	(115) *Thyra*	1912 Dec. 5	19h 52m.2	6h 21m.16	+ 38° 58′.8

By interpolation from the computed ephemerides of the planets, theoretical positions were obtained for the observation dates as follows:—

		Berlin M.T.	α	δ
1.	(115) *Thyra*	1912 Dec. 4.808	6^h $22^m.2$	+39° 02′
2.	" "	Dec. 5.822	6 21 .1	+38 59
3.	(139) *Juewa*	Dec. 31.787	6 45 .3	+40 46
4.	" "	1913 Jan. 2.800	6 42 .9	+40 48
5.	(119) *Althæa*	Feb. 27.834	10 25 .2	+2 56
6.	" "	Mar. 2.854	10 22 .6	+3 15
7.	(105) *Artemis*	1912 Oct. 7.392	1 10 .0	+2 06
8.	" "	Oct. 10.442	1 07 .3	+1 25
9.	" "	Oct. 12.484	1 05 .6	+0 58
10.	(133) *Cyrene*	Dec. 6.449	5 29 .7	+32 2
11.	(115) *Thyra*	Dec. 31.348	5 48 .8	+36 21
12.	(139) *Juewa*	Dec. 31.443	6 45 .8	+40 45
13.	(119) *Althæa*	1913 Feb. 25.481	10 27 .2	+2 40
14.	(115) *Thyra*	1912 Dec. 5.865	6 21 .1	+38 59

A comparison between the observations and the theoretical positions gives the following residuals:—

		Δα (*O*—*C*)	Δδ (*O*—*C*)
1.	(115) *Thyra*	$+0^m.1$	0′
2.	" "	+0 .1	0
3.	(139) *Juewa*	+0 .1	0
4.	" "	+0 .1	—1
5.	(119) *Althæa*	0 .0	0
6.	" "	0 .0	+1
7.	(105) *Artemis*	—0 .3	—1
8.	" "	—0 .1	—1
9.	" "	—0 .3	—1
10.	(133) *Cyrene*	+0 .7	—1
11.	(115) *Thyra*	+0 .3	—1
12.	(139) *Juewa*	—0 .1	+1
13.	(119) *Althæa*	0 .0	0
14.	(115) *Thyra*	+0 .1	0

With the exception of the α residual for (133) *Cyrene*, and the α residuals for two positions of (105) *Artemis* and for one of (115) *Thyra*, all of these being Heidelberg observations, the residuals are zero or within the errors of computation. No reason can be assigned for the three α residuals of $0^m.3$ each, except that the Heidelberg observations are only approximately given; but with reference to the $0^m.7$ residual for (133) *Cyrene* it may be said that the tables for that planet could not have been expected to hold as accurately as the others, because its mean motion is roughly commensurable with that of *Jupiter*, in which case HANSEN'S method is more or less indeterminate. Whether the residual is due to this cause or to neglected perturbations or to the inclusion in the final correction of the elements of a position erroneously identified by the observer, will form the subject of further investigation.

Thus several years after the last comparisons were made, the theoretical positions based upon LEUSCHNER'S tables are found to check almost exactly with the observations. The correction to the 1915 *Jahrbuch* ephemeris for (139) *Juewa*, noted in No. 4625 of the *Astronomische Nachrichten*, is not confirmed by the preceding comparisons.

BERKELEY ASTRONOMICAL DEPARTMENT,
UNIVERSITY OF CALIFORNIA,
1913, April.

THE DAVIDSON TRANSIT AND ZENITH TELESCOPE

BY OSCAR W. LANZENDORF.

When the Students' Observatory was organized more than twenty years ago, a Davidson transit and zenith telescope similar to the kind then in use in Coast Survey work was installed. It is equipped with a 3-inch object glass, latitude circle, striding level, and a micrometer which can be used in right ascension or declination. It is used mainly to determine time, latitude, and longitude.

During its twenty years' service it has been constantly used by students. Due to the more or less rough usage it has thus received, and to general wear, the instrument no longer gave consistent results. These anomalies were investigated by Messrs. P. W. STONER and H. J. KESNER in 1910-11, and as a result the instrument was sent back to the makers in 1911 to be remodeled. Upon its reinstallation at the observatory it was necessary again to determine its constants, which may have been changed as the result of remodeling.

In this work all of the constants were determined, but only the pivots and the micrometer are discussed here.

The inequality and ellipticity of the pivots were determined by the ordinary method of applying the spirit level to the outer surfaces of the pivots at properly chosen zenith distances. The values thus obtained were plotted upon co-ordinate paper. The curves show that the inequality, p, tends to decrease by a small amount with the zenith distance from 0° to 90° and then to increase with increasing zenith distances from 90° to 135°. This variation is probably due to ellipticity of the pivots, but the curves obtained for this ellipticity do not disclose any particular variation. The inability to show any decided variation of this kind can be said to be due to the method of observation with which the values were obtained; the instrument must be reversed by hand, which process tends to jar the different parts and so produce large unavoidable errors of observation. Since the ellipticity is of the order of these large errors of observation, it is not brought out. It is possible that when the new automatic reversing apparatus is installed, which reverses the instrument without jarring it, the ellipticity can be determined.

An average value of the inequality of the pivots was therefore adopted: $p = 0^s.047 \pm {}^s.001$; being the mean of thirty-four determinations.

The micrometer screw was investigated in detail, using the circumpolar star method, the value of one revolution being determined for each part of the screw. It was found to have a decided variation between R = 59″.8 and 60″.0; about 0″.2 per revolution over a range of forty revolutions. A curve was plotted with values of one revolution as ordinates and number of revolutions as abscissæ, showing the variation for the length of the screw. The curve has a typical symmetrical wave-form, two waves in length, having a wave-length of thirteen revolutions and an amplitude of about 0″.1. This curve was obtained from calculations based on six sets of determinations, comprising 328 observations on circumpolar stars.

Since the success of TALCOTT's method of determining the latitude depends upon the accuracy of one revolution of the micrometer, tables were constructed with the aid of mechanical quadratures which give the micrometer interval directly without reference to the plotted curve.

Several determinations of the latitude of the Students' Observatory have been made in the past, wherein the results by certain pairs of stars do not agree well with those from other star pairs. This disagreement will be investigated upon the basis of the now well-determined variation in the value of one revolution of the micrometer, and it is expected that the results from different pairs will then be found consistent.

BERKELEY ASTRONOMICAL DEPARTMENT,
UNIVERSITY OF CALIFORNIA,
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THE ABSOLUTE SCALE OF STELLAR MAGNITUDES.

By R. H. Tucker.

All attempts to grade the stars according to their brightness are based upon the adoption of an arbitrary scale, the basis of which may be said to be the order of magnitudes first given to the brighter stars by the earliest naked-eye observers. The sixth magnitude is ordinarily taken to be the limit of naked-eye visibility, though for practiced observers, with keen vision, the seventh magnitude may be set as the limit. The ratio of brightness found to exist in the early estimates corresponds to the number whose logarithm is 0.4; that is, in passing to a brighter grade the ratio is approximately 2.5, and in passing to a fainter grade the inverse ratio is 0.4, in terms of the light.

Modern adjustments of the scale of magnitudes are usually based upon the adoption of the sixth magnitude from existing Uranometries, and with fairly close adherence to the ninth magnitude of Argelander, as given in the first *Durchmusterung* for the northern sky. Observers with telescopes have in general endeavored to establish a scale in conformity with this range of the so-called "historic scale."

It must be noted that, for the brightest stars, visual estimates made with a telescope are not likely to be as precise as those made with the naked eye. In any case, the distinction of the gradations of brightness towards the fainter end of the scale, visible under certain conditions, can be more precisely made. The faintest stars visible with the naked eye can be very accurately gauged; and, similarly, the faintest stars visible in a telescope should be classified most easily. The illumination of the field of view enters as a factor, and may be said to act as a photometric aid. Thus, in the telescopes of the usual type of meridian circle, stars from eighth to tenth magnitude can be quite precisely graded, while, without illumination, fainter stars would be visible, and would be easily classified. For stars between sixth and eighth magnitude, fairly close estimates may be expected; and, with considerable practice, the scale can be carried down to fourth magnitude. Beyond that point the lack of frequent observations of bright stars in ordinary observing experience, and the very noticeable variation in the quality of the images of bright stars, due to different conditions of steadiness and definition, make the estimates of the brightest stars with a telescope very uncertain.

In using the 36-inch telescope, for the purpose of establishing standards of visual magnitude for the faintest stars visible, in the early nineties, the range of magnitude from the fourteenth to the seventeenth inclusive could be quite closely estimated; while it would have required a great deal of experience with that instrument to estimate the relative grades of stars brighter than these classes. The same region had been previously charted with the Harvard College 15-inch and the Washington 26-inch, each telescope having added approximately one unit of magnitude at the fainter limit. The *Uranometries*, with naked-eye estimates, furnish the visual scale for the brightest stars; small telescopes carry the scale down to fainter stars, and the largest instruments are necessary for visual estimates of the faintest grades. The errors of absolute scale may be conceived as cumulative, in thus establishing the scale of visual magnitudes; but the limit of visibility with any size of telescope, used with dark field, is a check upon the faint end of the scale, and the faintest stars seen are very likely to be brighter than the theoretical limit of visibility.

The photometer, in various forms, is an instrumental device for extending the scale of magnitudes in both directions from the standard type, which is assumed to be the historic sixth magnitude of the visual scale. The results of measures with the photometer are based upon comparison with the visual estimates.

The process followed is either to equalize two sources of light, one the star whose brightness is to be measured, the other source being an artificial star, or a standard star, whose beams are reflected into the same field of view; or to determine the point at which the light of the real star is extinguished, and measure the extinction employed.

For varying the amount of light from either source, wedges of partially opaque glass can be used, sometimes darkened by the photographic process; or methods of reflecting a part, or all, of the light may be used.

While it is often contended that photometric work consists of measures in place of simple estimates, and that therefore the results should be more reliable, it should not be forgotten that the result of every measure depends, originally or finally, upon the human judgment in some form. In photometric work, the estimation of exact equality of two sources of light, or of entire extinction, may be more precise than any estimation of relative difference of light, but the element of personal judgment cannot be entirely eliminated. Photographic determinations of the brightness of the stars contain the personal element also, when the comparison of star images is made. Both these instrumental methods depend to some extent upon comparison with adopted visual estimates, of a part of the scale at least, for establishing the basic type, and for checking the theoretical variation of their measures with variation of type. It is possibly open to question whether the results of either form for the brightest stars are improvements upon the best visual naked-eye *Uranometry* magnitudes, such as those of GOULD in the southern hemisphere.

The extension of the scale to the fainter stars is, however, more in line with the purpose of this note.

In the endeavor to give an expression which will represent the actual distribution of the stars according to brightness, two assumptions are generally made at the start, neither of which is believed to be more than partially valid, for more than a limited part of the scale at most. These assumptions are: uniform distribution in space and equal intrinsic brightness. The first assumption is at once contradicted by the known clusters, the groups of stars, and the vast stream of the Milky Way. Still, by taking large areas of sky, the law of distribution can be tested, as far as it concerns the various types of brightness. The second assumption is contradicted by the fact that we know that there must be a large range of size among the stars from the study of their masses, and we also recognize from the sequence of the various spectral types that there is a process of evolution, by which the stars develop, and all degrees of brilliancy may be represented, from the newest stars to those partially burned out, or, in the case of the "dark stars," the light may have been totally extinguished.

The two assumptions would make the brightness the direct and only criterion of distance, while there are many cases in which faint stars are known to be nearer to us than some of the brighter stars. The expression based upon these two assumptions can be used as a test of the distribution, and its variation from counts of stars should show how far such assumptions may fall short of explaining actual conditions.

The expression for the summation of the number of stars to any order of brightness is usually put in the form—

$$\Sigma\, m = a\, b^m$$

In this expression m is the limiting magnitude, a is the number of stars for unit radius, and b depends upon the assumptions first made. If rigorously true, b would equal $\delta^{3/2}$, when δ is the ratio of brightness for a difference of one magnitude; the volumes being proportional to the cubes of the radii of the enclosing spheres, and the brightness of the stars being inversely proportional to the squares of their distances.

The theoretical value of b would thus be the number whose logarithm is 0.6, or 3.98. It would then correspond to the ratio of volume for a decrease of one magnitude in the scale.

The law which is expressed by the above formula for the summation is known as that of the absolute scale of magnitude. Visual estimates have endeavored to conform to this law, in establishing the visual scale; photometric measures are based upon the same law; and photographic measures of star images are made to conform to the law, by comparison with the established scale. As counts and estimates of the actual numbers of faint stars become available, the value of b can be determined at various points in the scale, treating it as a variable quantity, to conform to the deviation of fact (real distribution) from theory (uniform distribution and equal brightness), by the original assumptions.

This is a convenient process also for the tests, since b can be determined at any point of the scale, by the comparison of the summations of two grades, leaving the quantity a invariable.

The values of b have been found to diminish, for the faintest grades of brightness. This would be anticipated, unless the total number of stars in the universe were assumed to be infinite, and also from the fact that the whole amount of light received from the stars does not increase indefinitely. The successive values of b for small differences of magnitude may be expected to vary slowly, and the summation may then be used to test the scale itself, over a limited range at least.

Some applications of the theoretical law to actual counts will be made here.

The northern *Durchmusterung* of ARGELANDER contains a practically complete list of the stars to ninth magnitude for one half of the sky, and the southern *Durchmusterung* provides, in its several parts, a similar list for the other half. A systematic count of the northern *Durchmusterung* was made by LITTROW, and published in the 1869 *Sitzungsberichte* of the Vienna Academy of Sciences, and it is printed in GOULD'S *Uranometry*, in his discussion of the distribution of the stars. The numerical expression for the summation of the faint stars, to 9.0, in the northern sky, has the following form:

$$\Sigma m = 0.5208 \, (3.8685)^m.$$

It is the portion of the scale from 7.0 to 10 which has the most interest just here; with later its extension downwards beyond the limits of the visual *Durchmusterung*. For this reason, it has appeared worth while to give the count of ARGELANDER in detail for this portion, especially since a similar count is already on record, for a part of the southern sky, in the note printed in the *Astrophysical Journal* for May, 1898. The following table is taken from LITTROW'S count, and the summation has been made for the separate tenths of each magnitude:—

TABLE I—ARGELANDER'S NORTHERN *DURCHMUSTERUNG.*

Mag.	No.	Σ	Per 1000	Σ	*b*
Br.	....	5,876	..	19	3.866
7.0	2,141	8,017	7	26	3.965
7.1	345	8,362	1	27	3.911
7.2	984	9,346	3	30	3.898
7.3	1,356	10,702	4	34	3.907
7.4	516	11,218	2	36	3.851
7.5	2,860	14,078	9	45	3.899
7.6	609	14,687	2	47	3.851
7.7	1.537	16,224	5	52	3.834
7.8	2,484	18,708	8	60	3.837
7.9	991	19,699	3	63	3.792
8.0	5,622	25,321	18	81	3.853
8.1	1.778	27,099	6	87	3.822
8.2	3.650	30.749	11	98	3.818
8.3	4,609	35,358	15	113	3.822
8.4	3,101	38,459	10	123	3.798
8.5	9,788	48,247	31	154	3.840
8.6	4,189	52,436	13	167	3.817
8.7	6,799	59,235	22	189	3.812
8.8	10.963	70,198	35	224	3.827
8.9	7.596	77.794	24	248	3.813
9.0	23,277	101,071	74	322	3.869
9.1	15,615	116,686	49	371	3.872
9.2	20.734	137,420	66	437	3.884
9.3	31,278	168,698	99	536	3.913
9.4	34.951	203,649	111	647	3.935
9.5	111,276	314,025	353	1,000	[4.061]
		Σ	1,000	mean	3.858

In the above table the stars brighter than 7.0 have been placed in the first group. The irregular variation of the numbers, for successive tenths of the scale, is noticeable. This is due to the fact that ARGELANDER estimated to half magnitudes only, hence the 7.5 and 8.5, and the even units will naturally preponderate. Also it is evident that the mean of 7 and 7½ was rated as 7.3, in the published scale by tenths; the mean of 7½ and 8 was rated as 7.8, in tenths; and the same convention was adopted throughout. The other tenths of the scale are derived from three or more observations.

The average number, per thousand stars of the faintest grade inclusive, is given, in the table, for convenience of expressing the distribution in a form which is evident at a glance. Taking the adopted value of *a*, 0.5208, for the summation to 9.0 in the northern sky, the values of *b* have been computed for each tenth. The value for 9.5 shows at once the elastic nature of that grade; it was intended in the original estimates to include 9½ and fainter stars, and the computation of the individual values of *b* shows that the mean, 3.86, corresponds to the summation to a grade between 9.8 and 9.9 on the same scale of magnitudes. To give the number equivalent to the summation to that point, stars as faint as 10 were probably observed. All of the grades, by tenths, fainter than 9, are somewhat in excess, also, and it is evident that the observed scale changed slightly at that point, and that stars of the fainter classes were generally estimated too bright.

The number of stars included in the grade 9.0 is in excess, apparently, by about 8,000, as compared with the grades each side; and the numbers at the other even units are in similar proportional excess. ARGELANDER expressed the opinion that the stars of ninth grade were probably too numerous, in his classification; but the test supplied by the table indicates a fairly consistent scale to ninth magnitude.

The results of a count of magnitudes, by tenths, in the first ten degrees of the Córdoba *Durchmusterung*, are given in the following table, as they were originally published in the *Astrophysical Journal*. Some 37,000 stars were included in that count. The tabulation of stars per thousand is made in the same form as that used above for the northern region. The lowest grade, 10, at Córdoba was an elastic one, and included many stars that were consciously estimated to be much fainter than tenth magnitude. This was necessary, to some extent, in order to be sure of including all stars of tenth magnitude. The numbers at the half magnitudes and even units of the scale are generally somewhat in excess. The progression in the other tenths is nearly uniform, since the original estimates by quarters include more than two observations for a large proportion of the stars. The average per thousand refers, of course, to the total summation.

TABLE II—FIRST TEN DEGREES OF CÓRDOBA D. M.

Mag.	Per 1000	Σ	*b*	Mag.	Per 1000	Σ	*b*
Br	..	6	3.88	8.5	10	57	3.95
7.0	2	8	3.96	8.6	8	65	3.95
7.1	1	9	3.93	8.7	11	76	3.96
7.2	1	10	3.95	8.8	10	86	3.95
7.3	1	11	3.95	8.9	11	97	3.95
7.4	1	12	3.91	9.0	24	121	3.98
7.5	3	15	3.95	9.1	23	144	4.00
7.6	1	16	3.93	9.2	26	170	4.01
7.7	3	19	3.94	9.3	27	197	4.01
7.8	2	21	3.93	9.4	33	230	4.02
7.9	2	23	3.90	9.5	54	284	4.05
8.0	5	28	3.93	9.6	63	347	4.07
8.1	4	32	3.93	9.7	87	434	4.11
8.2	5	37	3.93	9.8	100	534	4.14
8.3	6	43	3.94	9.9	86	620	4.14
8.4	4	47	3.92	10.0	380	1,000	[4.28]

The values of *b* in the table are fairly uniform and constant from seventh to ninth magnitude, at which point they begin to increase perceptibly. This indicates that the scale of the estimates begins to change at ninth magnitude, the faint stars being estimated too bright. ARGELANDER's scale indicates a similar change, beginning at 9¼. In either case the increase could be explained by an increase in the actual numbers of faint stars; but such an assumption is far less probably true than changes in the personal estimates. The 10 of Córdoba, understood to be an elastic grade, includes the equivalent of the total number of stars to 10.5 of its own scale, if we adopt the value of *b* at 9.0 of that scale. If, however, we allow for the increase in *b* from 9 to 9.9, then the 10 of the catalogue includes a number equivalent to the summation to 10.2 of this slightly varying scale.

Unless there are actually numbers of faint stars between ninth and tenth magnitude in excess of the proportion of brighter stars, each of the two scales, from ninth magnitude to the fainter limit, can be corrected on the basis of the summation at ninth magnitude by the summation at the individual tenths, and this has been done below. The correction to ARGELANDER's scale does not become important until 9.3 is reached. The faintest grade, 9.5, would be below 9.8 on its own scale.

The correction to the Córdoba scale becomes sensible at 9.5, amounts to two tenths at 9.8, and the correction to the ten of the scale is probably the same amount. The 10 of the catalogue, however, is equivalent to the inclusion of stars to 10.4. The Córdoba estimates by the comparison of numbers, are two tenths brighter than ARGELANDER, at ninth magnitude: and this difference has been applied to derive the equivalent of the corrected ARGELANDER scale, in the last column, for the Córdoba estimates. The comparison of the total numbers of stars in the two catalogues indicates an extension of the Córdoba scale to 0.9 magnitude beyond the limit of ARGELANDER; and the faint 10 of Córdoba thus corresponds to the true 10.7 of ARGELANDER. The 9.5 and 9.6 of Córdoba are probably brighter, on the average, than the 9.5 of ARGELANDER, which is nearly the same as the 9.7 of Córdoba.

TABLE III—CORRECTED MAGNITUDE SCALE OF FAINT STARS.

Argelander Mag.	Nor. D. M. Corrected.	Córdoba — 32° Corrected.	Reduced to Argelander.
9.1	9.10	9.12	9.3
9.2	9.22	9.23	9.4
9.3	9.37	9.33	9.5
9.4	9.51	9.43	9.6
9.5	[9.82]	9.58	9.8
9.6	...	9.71	9.9
9.7	...	9.86	10.1
9.8	...	10.00	10.2
9.9	...	10.10	10.3
10.0	...	[10.43]	[10.6]

In the discussion of the photometric scale of magnitudes, in a recent volume of the publications of the Harvard College Observatory, *Harvard Annals,* **72,** page 84, there is a reference to the summation of the Córdoba *Durchmusterung* for the zone — 49°. On the basis of the number of stars in this zone of one degree, the total number of stars in the sky down to the same limit of brightness is found to be 2,533,000. This is an average of sixty-one stars to a square degree; while the first two Córdoba volumes, for the region — 22° to — 42°, give an average of fifty-five stars, which would be equivalent to 2,269,000 stars for the area of the whole sky. The increase in number in this case does not necessarily imply a definite extension of the magnitude scale, which was intended to be complete to the tenth magnitude only, but probably a slightly increased proportion of faint stars, below the limit of completeness.

This enumeration was compared with the numbers for the photometric scale, published in *Harvard Annals*, **48**, Table XXI, page 178, and the conclusion was drawn that the Córdoba scale includes an equivalent of the photometric scale to the twelfth magnitude. There is evidently a large difference between the respective scales, for the faint stars.

The photometric scale given in Table XXI, Volume 48, was based upon counts and estimates of stars, of various degrees of brightness, down to the magnitude 13.5. The counts were plotted, and a curve drawn, from which the figures corresponding to distribution were taken. Reference to the original volume should be made for the details of the process. The method is based upon the law of absolute magnitudes; and in the expression $\Sigma m = a b^m$, the a is determined from a comparison of the counts with the respective volumes, and is then adopted as a constant 3.7. The b is taken as variable, its value being derived from the smoothed curve, and ranging from 3.34 at magnitude 0, to 2.95 at 13.0, when computed from the respective summations at these points of the scale. The values of b are tabulated below:—

TABLE IV—PHOTOMETRIC SCALE.
(*Harvard Annals*, 48, Table XXI.)

Mag.	Stars.	b
7.0	14,960	3.27
8.0	45,710	3.26
9.0	134,300	3.21
10.0	373,300	3.16
11.0	957,200	3.11
12.0	2,239,000	3.03
13.0	4,786,000	2.95

The values of b in the sequences in this table are naturally smoothed out by the process used in forming the numbers. The numbers of stars have been computed for the whole sky, hence, in making comparisons with those of ARGELANDER, the figures of the latter must be doubled. The number of ninth magnitude stars in the sky by ARGELANDER's scale would be 202,000, and, by the Córdoba scale, 275,000; hence the photometric summation at ninth magnitude has only two thirds of ARGELANDER's enumeration, and one half that of Córdoba (first ten degrees).

There is some uncertainty in the direct comparison of the numbers, since the photometric scale is summed up to half magnitudes, and the visual scales to tenths. According to a note from Professor PICKERING, of date March 10, 1913, the tabulation to ninth magnitude includes the stars up to that grade, exactly; hence, to make this enumeration correspond to the visual scale, a number equivalent to the half of the number of stars per tenth magnitude of the latter should be added to the photometric enumeration. This would be about 8,000 at ninth magnitude, a small percentage.

Since the relative brightness of the various scales at ninth magnitude is a most important basis of comparison, the numbers from the two remaining parts of the *Durchmusterung* should be considered here. The *Cape Photographic Durchmusterung* contains about 455,000 real stars in the area from — 19° to the south pole, which is about 67 per cent of the southern hemisphere. Of these stars, 81,481 are given as magnitude 9.0 or brighter, about 18 per cent. This enumeration is equivalent to 243,000 ninth magnitude in the whole sky, or about 1,350,000 stars down to the lowest grades included in the photographic catalogue.

There is a rather sharp division in the catalogue at — 34°, which I discussed, to some extent, in the note in the *Astrophysical Journal*. The percentage of ninth magnitude stars drops from 23 per cent north of — 34° to 16 per cent south of that point. The lower limit of the catalogue was extended a full quarter of a unit of magnitude, but the estimated ninth magnitude type has apparently remained the same. The limiting faint type of star has been raised, in total number for the sky, from one million to one and a half million, by this change in extension.

In SCHÖNFELD's southern *Durchmusterung* of 133,000 stars, in the area — 2° to — 22° inclusive, 34,119 stars are of 9.0 and brighter, according to count by SEELIGER,[1] or 25.7 per cent.

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[1] *Cape Annals*, IX, page 185 B.

The equivalent of his full catalogue would be 747,000 stars for the whole sky, or 192,000 stars to 9.0 inclusive. This last number is slightly smaller than ARGELANDER's summation, and much below the Cape Photographic and Córdoba first ten degrees. SCHÖNFELD's summation at 10 and 9.0 would give the value of b 3.898, which indicates that his scale is probably consistent throughout, to the lowest grade.

With the value $b = 3.9$, the photographic limits would be 10.08 and 10.34, above and below — 34° declination, on its own scale. Its catalogued stars vary from 9.6 to 11.4 at the lower limits, for various parts of the sky. The feature of the photographic catalogue which appears most difficult to understand is the small numbers and wide range of the faintest stars recorded. It would be expected that the photograph would give a very definite limit of brightness, at which the faintest grade would be very nearly complete.

It remains to translate the four scales into the photometric scale, according to the respective enumerations. The basis is table XXI, *Harvard Annals*, **48**, page 178, already referred to above.

ARGELANDER and Córdoba are given in detail, for the fainter grades, for which counts and close estimates of numbers exist.

TABLE V—PHOTOMETRIC MAGNITUDES OF D. M. SCALES.

Mag.	Argelander.	Córdoba.	Schönfeld.	Cape.
7.0	7.06	7.17	...	...
8.0	8.09	8.30	...	...
9.0	9.39	9.69	9.34	9.58
9.1	9.54	9.86	...	...
9.2	9.69	10.03	...	...
9.3	9.90	10.18	...	...
9.4	10.09	10.34	...	...
9.5	[10.53]	10.71	...	...
9.6	...	10.78	...	...
9.7	...	11.03	...	...
9.8	10.5	11.26	...	...
9.9	...	11.43	...	...
10	...	[12.02]	10.70	
10.1	...	...	...	11.1
10.2	...	...	...	...
10.3	...	...	...	11.5
10.4	...	12.0	...	...

From the above photometric basis of enumeration, Córdoba estimates would appear to be one tenth brighter than ARGELANDER at seventh magnitude; two tenths at eight; three tenths at ninth; and three quarters of a magnitude brighter at the faint limit of ARGELANDER, which is 9.8 of its own scale.

SCHÖNFELD and ARGELANDER are in close agreement at nine and ten of both scales.

The Cape Photographic estimates are one tenth fainter than Córdoba at ninth magnitude, and its faintest grades correspond nearly to Córdoba 9¾ and 10, above and below —34° declination, respectively, or about three tenths fainter than the Córdoba scale.

ARGELANDER'S scale gives estimates one tenth brighter than the photometric at eighth magnitude; four tenths brighter at ninth; increasing to seven tenths brighter, for the faintest stars of the northern *Durchmusterung.*

As a further test of the difference between the photometric and visual scales, the following comparison has been tabulated from the separate results recently published in *Harvard Annals,* 72, which includes estimates made by Professor BAILEY at the time of the photometric measures. These last estimates are individually, and collectively, very uniformly consistent with the Córdoba magnitudes, with a slowly progressive increase of difference. The average residual appears to be smaller than would be encountered among the separate independent estimates of the observation made for the *Durchmusterung.* The comparison extends through the whole circuit of right ascension, for parts of the zone —29° 50′ to —30° 0′. Only 1,133 of the *Durchmusterung* stars were measured, while the 10′ belt contains about 3,000 stars, and some of the brighter stars lie outside the belt.

The differences of the table are given for quarter magnitudes, three individual tenths being combined, and the unit magnitudes being given separately.

As before noted, the range of the photometric scale is nearly double that of the visual, between these limits, 3.8 units against Córdoba two units; or 50 per cent larger, if the Córdoba ten be assumed to extend to 10.4 of its own scale.

TABLE VI—DIRECT COMPARISON OF PHOTOMETRIC AND CÓRDOBA VISUAL SCALES.

D M Mag	No.	Phot. Mag.	Δ	Bailey.	Δ
Br.	43	...	+0.18	...	+0.19
8.0	31	8.26	+0.26	8.34	+0.34
8.1	9	8.45	......	8.41	......
8.2	11	8.55	+0.37	8.65	+0.37
8.3	23	8.72	......	8.64	......
8.4	11	8.64	......	8.82	......
8.5	23	8.82	+0.39	8.89	+0.43
8.6	19	9.22	......	9.07	......
8.7	30	9.27	......	9.10	......
8.8	20	9.36	+0.57	9.15	+0.37
8.9	20	9.49	......	9.25	......
9.0	64	9.74	+0.74	9.46	+0.46
9.1	54	9.97	......	9.54	......
9.2	43	10.27	+1.02	9.69	+0.46
9.3	58	10.43	......	9.74	......
9.4	58	10.58	......	9.85	......
9.5	55	11.00	+1.41	9.98	+0.49
9.6	86	11.14	......	10.15	......
9.7	98	11.49	......	10.31	......
9.8	55	11.61	+1.82	10.47	+0.63
9.9	46	11.76	......	10.52	......
10.0	276	12.08	+2.08	10.76	+0.76

The estimates of BAILEY are close to the photometric scale at the bright end, but are 1.3 magnitude brighter at the faint end.

The direct comparison shows that the photometric measures are much fainter than the visual estimates and the photographic measures, for all the fainter grades of stars. The comparison of the respective summations of stars included gives the same indication. In the summations, the values of *b* in the photometric scale are smaller than generally accepted for the so-called absolute scale of magnitudes. On the other hand the value of *a* is large; that adopted in the formula for the northern *Durchmusterung* being only slightly in excess of unity (1.04) for the whole sky, or less than one third of the value derived for the photometric. No account has been made here of the possible loss of light by an absorbing medium in space. In general, the decrease in *b* indicates an approach to the limit, not only of the stars visible, but of actually existing stars.

May 13, 1913

A PLEA FOR MORE AMATEUR VARIABLE-STAR OBSERVERS.

By Edward Gray.

Of all the scores, perhaps literally hundreds, of telescopes in this country in the hands of amateurs, how many are producing results tangible and accessible to science? Is not a great waste of optical equipment going on? Is it not true that after a period of recreation among the double stars, the planets, and the Moon the telescope too often gets set aside for want of an aim by which it can be profitably used?

At this stage why are the variable stars so sadly neglected? Excepting the observation and discovery of comets is there any other line more directly open to amateurs in which the observer may do original work that shall count and in which his results may be made useful to the present and to future generations?

The object of this paper is to set forth how inviting and remunerative a field to amateurs the observation of long-period variables is. In the first place, one's equipment need not be very elaborate nor highly expensive. For a small minority of observations a good field-glass will suffice, but for the large majority a telescope of some aperture between two and six inches, or a reflector of four to eight inches in diameter, is desirable. As a matter of fact, two members of the Variable Star Association of our country use very small refractors—namely, one of two and a half and one of two inches,—and each does good work therewith. Nor is an equatorial mounting at all essential; probably the majority of us use a tripod mount. This means, of course, much more work at first in getting acquainted with the fields, but rapid work thereafter. I have, for example, a recent letter from a highly valued correspondent who uses a three-inch refractor on a tripod mount, giving a list of twenty-six estimates made that evening, the telescope being back in the house by 8:50. This is adduced merely to show what familiarity will accomplish.

The stars to be observed are variable in very different periods, from two months to well nigh two years. Some are therefore increasing, some decreasing, in brightness: a few are at maximum, others at minimum, and still others resting before either rising or falling. All this insures variety; there is nothing humdrum about observing variable stars. Surprises are frequent and one's interest is kept on the *qui vive;* for while some stars are perfectly regular and move like clockwork, others are irregular enough in their fluctuations to furnish all the mystery necessary. Some are white, some yellow, some orange, some red, and a star red at or close to minimum may become orange near maximum. It does not follow that because SS *Cygni* performed its cycle in nine weeks, three or four months ago, that it will do the same at the next period. In fact on the 15th of March I found it at maximum only forty days after the previous one—an observation unique in my acquaintance with this star.

Seldom does one devote himself for six or more months to this line of research without describing it as fascinating. And if the mere observing is charming and fascinating, what shall we say of the intellectual profit and expanse of the mind to be attained thereby? For, be it known that there are problems connected with these stars which may exercise even the best intellects. Why do some variables, like R *Hydræ*, shorten their periods and others, like χ *Cygni*, lengthen theirs? Why does *Mira Ceti* sometimes hardly exceed the fifth magnitude at maximum and at others reach almost the second? Why, again, does this same star descend only to the eighth magnitude at some minima, but at others to the ninth, or 9½, and why should it vary to the extent of twenty days in either direction from its mean period of 331⅓ days? What physical cause is there why U *Geminorum* and *SS Cygni* should remain close to minimum for weeks or months and then suddenly rise, attaining maximum in two days or less? Why do very red stars usually have very long periods? And so forth to more complex queries.

Besides the telescope—and some place to use it—there are needed only a good star atlas and a number of charts of the variables to be studied. The intending observer should associate himself with the American Association of Variable Star

Observers or with the Society for Practical Astronomy. The necessary charts are procurable from the members or directly from the Harvard College Observatory. Patience and perseverence do the rest.

It can only be ignorance of the pleasure and the usefulness, combined, of variable-star observing which has so far deterred amateur observers. One great obstacle has been the want of a primary volume on this branch. This is to be met within two years by Father HAGEN.

At present the literature is scattered in various magazines. The beginner's path is now, however, distinctly easier than it was three years ago. The magazine *Popular Astronomy* gives each month a report of the work of our association, the observations now numbering 700 to 1,100 per month, according to weather; but more observers are needed to carry on the work properly.[1]

Is it not practicable to establish a variable-star section in our own society? What is needed other than a director inspired with zeal for the cause?

A vast number of observations is needed for study and to accumulate the data required for elucidating the many problems related to variable stars. Who will volunteer to take hold and help and in the process become fascinated?

Let me now present the claims of variable stars in résumé:—

1. It is the chief line open to amateurs in which they may do good work and turn their telescope power to useful account. Many hundreds of thousands of such observations are required for the purpose of the professional astronomer and the field is open, with no crowding.

2. This pursuit has a charm which must be experienced to be appreciated. It does not pall nor grow monotonous.

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[1] To support this statement, let me quote from the *Annals* of the Harvard College Observatory, Vol. LV, p. 39, (italics mine):—

"062508 X *Monocerotis.*—A period of 163 days satisfies many of the measures made on Harvard photographs from March 24, 1888, to November 13, 1901; but there are large irregularities, and assuming this period, the variable was sometimes at or near minimum at computed dates of maximum. The form of the light-curve and range of variation are also very irregular. The spectrum of the star is that which is characteristic of long-period variables. *Very few visual observations have been published.* Since it does not appear to go below the tenth magnitude, *it could easily be followed with small telescopes, and continuous observations, when the star is not too near the Sun, are needed to learn the nature of the changes of this interesting variable.*"

3. It has an educative and intellectual value of its own. This can be better understood after a practical acquaintance with the pursuit.

4. It is not costly.

5. It leads to the formation of desirable acquaintances for a most cordial *esprit de corps* exists among its devotees.

6. It requires method in observing and recording results, and leads to habits of exactness; likewise to the setting of problems to be worked out and to a desire for higher knowledge. Its influence is wholly wholesome upon mind and brain and temper. It is an uplifting pursuit.

7. It is constructive, not destructive, and adds to the sum of human knowledge.

In view of this presentation, will not a few of you join the ranks of the observers? I should be glad to assist any novice in making a right start, remembering the difficulties which confronted me at the outside for want of accessible advice.

[illegible], Cal.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1913.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

New Moon	July 3, 9^h 6^m P.M.	New Moon ...	Aug. 2, 4^h 58^m A.M.
First Quarter	" 10, 1 37 P.M.	First Quarter...	" 8, 8 3 P.M.
Full Moon	" 17, 10 6 P.M.	Full Moon	" 16, 12 27 P.M.
Last Quarter.	" 26, 1 59 A.M.	Last Quarter...	" 24, 4 18 P.M.
		New Moon ...	" 31, 12 38 P.M.

The third eclipse of the year, a partial eclipse of the Sun, occurs on August 31st. The region of visibility is from Greenland to Nova Scotia. The eclipse is a small affair devoid of scientific interest, the maximum obscuration of the Sun being only 15 per cent of its diameter.

The Earth is in aphelion on the afternoon of July 3d.

Mercury is an evening star at the beginning of July, setting rather more than an hour and a half after sunset, and the interval does not diminish to an hour until after the middle of the month, so it may be easily seen during the evening twilight. It comes to greatest east elongation on the morning of July 7th, the apparent distance from the Sun being then 26° 13′, a considerably greater distance than at the average greatest elongation, this because the planet reaches aphelion on July 16th, only nine days after greatest elongation. After the time of greatest east longation the planet approaches the Sun and passes inferior conjunction on the morning of August 4th, becoming a morning star. The distance from the Sun increases rapidly and the planet reaches greatest west elongation, 18° 26′, on the morning of August 22d, rather a small greatest elongation, because it passes perihelion on August 29th, only a week later. During the latter half of August *Mercury* will rise rather more than an hour before sunrise, and may be seen on clear mornings in the eastern twilight.

Venus is a morning star, rising a little less than three hours before sunrise on July 1st. This interval increases about half an hour during the month and then diminishes slightly during August, being a little over three hours on August 31st. It reaches greatest west elongation, 45° 44′, on the afternoon of July 3d, and from that time the apparent distance between planet and Sun diminishes, but on account of the increasing northerly distance of the planet relative to the Sun the interval between the rising of the planet and sunrise increases for some weeks. During the two months *Venus* moves about 70° eastward and 4° northward among the stars from a position a little south of the *Pleiades* in *Taurus* through that constellation and *Gemini* into *Cancer*. In its easterly motion it passes *Saturn* at a distance of 1° 18′ to the south on July 21st, and also comes to conjunction with *Neptune* on the afternoon of August 29th, the latter planet being only 18′ north of *Venus* at the time of nearest approach.

Mars rises a little after 1 A. M. on July 1st and shortly after 11 P. M. on August 31st, moving during the interval from a point in *Aries*, 43° eastward and 9° northward through that constellation to a position in the eastern part of *Taurus*. Toward the end of July it passes about 5° south of the *Pleiades*, and on August 12th about 5° north of α *Tauri*, *Aldebaran*, the principal star of the constellation. On August 24th *Mars* is in conjunction with *Saturn*, the former passing about one degree south of the latter. Its actual distance from the Earth diminishes about thirty millions of miles during July and August, and its brightness increases about 40 per cent during this time, being at the end of August about 28 per cent of its brightness at the next opposition in January, 1914.

Jupiter comes to opposition with the Sun on the morning of July 5th, and during this month is above the horizon practically the entire night. By the end of August it sets before 1 A. M. It is in the constellation *Sagittarius*, and during the two months moves about 6° westward a short distance north of the Milk Dipper group.

Saturn is drawing farther away from the Sun, rising a little before 3 A. M. on July 1st, and shortly after 11 P. M. on August 31st. It is in the constellation *Taurus*, a little north and east of *Aldebaran*, and during the month moves about 6° eastward. Its conjunction with *Venus* on July 21st and with *Mars* on August 24th have already been mentioned.

Uranus is in opposition with the Sun on July 28th and is consequently on the meridian at midnight. On July 1st it passes the meridian at about 2 A. M. and on July 31st at a little before 10 P. M. It moves about 2° westward and a little southward in the constellation *Capricorn*. No bright stars are near, but early in July the planet passes about one degree south of the fifth-magnitude star ν *Capricorni*.

Neptune is in conjunction with the Sun on July 18th and during July and August is too near the Sun even for telescopic view.

NOTES FROM PACIFIC COAST OBSERVATORIES.

Concerning Some Forces[1] Affecting Cosmical Motions.

It is well known that many cases of discrepancies have existed between the observed positions of bodies in the solar system and their positions as predicted upon the basis of Newton's law of gravitation. Some of the discrepancies have been explained and removed, whereas others still exist.

Halley's Comet returned to perihelion in March, 1759, several months later than the predicted time. It was not until the discoveries of *Uranus* and *Neptune* in 1783 and 1846, respectively, that astronomers were able to explain the discrepancy by virtue of the attractions due to these two planets.

Discrepancies in the motion of *Uranus* led to the discovery of the disturbing body *Neptune* in 1846—facts familiar to all students of astronomical history.

It has long been known that there are minute discrepancies between the observed and predicted motions of *Mercury*, *Venus*, the Earth, and *Mars*. Newcomb's interest in this problem led him to investigate the effects of undiscovered small planets situated between the Sun and the orbit of *Mercury*, or between the orbits of *Mercury* and *Venus*, and likewise of the finely divided matter responsible for the zodiacal light; but he concluded that forces due to such masses could not be the causes of the discrepancies. Seeliger's researches, on the contrary, have convinced him and others that the zodiacal-light material may be an extremely important factor in this problem; though, perhaps, this is not the only factor.

The most noteworthy case of discrepancy relates to our Moon, principally because the relative nearness of the Moon to the observer causes the discordances to have considerable angular magnitude; and these remain unexplained.

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[1] In this brief note there has been no effort made for completeness, by including eruptive, gas action, convection, and other minor forces; nor by referring to the important investigations of Leverrier and others.—W. W. C.

It is scarcely an exaggeration to say that successive generations of astronomers fully expected that NEWTON's law would ultimately be found to explain all such discrepancies, either through more perfect methods in the application of the law or through the action of disturbing bodies as yet undiscovered. The recent discoveries of forces and principles possessing quite different natures from those of gravitation have tended to weaken the view that NEWTON's law is all-sufficient.

Radiation pressure, discovered theoretically by MAXWELL and established experimentally by LEBEDEW and by NICHOLS and HULL, is far reaching in its consequences upon the cosmical motions of minute particles. In the case of comets' tails, for instance, radiation pressure seems to be more effective than gravitation; but this force appears to be negligible, at least for the present, when we are dealing with relatively large individual masses.

BROWN has investigated the possible effects of the Earth's magnetic force upon the motion of the Moon, only to conclude that this force is ineffective and negligible.

WACHER, LORENTZ, and DE SITTER have discussed the principle of relativity as a possible important factor in explaining existing residuals in the motions of planetary perihelia.

BOTTLINGER and DE SITTER have recently investigated the hypothesis that the mutual gravitational attractions of two bodies may be influenced by the passing of a third body between the first two; the intervening body absorbing, in effect, a certain amount of the original attractive force in accordance with laws depending upon the mass penetrated by the lines of force. There is some evidence that this hypothesis is an approximation to a fact of nature.

HALE's recent work has led him to the conclusion that the Sun is a weak magnet whose north pole is in a general way situated near the north geographic pole of the Sun. That the Earth and Sun, perhaps the only bodies available for such studies by means of existing resources, should prove to be magnets, of like polarity, argues strongly for the existence of magnetic forces in all other rotating cosmical bodies.

The effects of solar and terrestrial magnetism upon the motions of the Sun and Earth are no doubt negligible for the present, but may it not be that similar forces under other cosmical conditions are highly effective? Consider the case of a close spectroscopic binary system, whose period of revolution is only a few hours or only a few days. We have very strong reasons for believing that the two massive components are rotating on axes essentially parallel, in the same direction with reference to their surroundings, once in each revolution period. If the rotation of a sun or a planet is an important factor in developing its magnetic field, may not the two rapidly-rotating components of the double-star system be magnets of great strength? Is it not probable, further, that they are of like polarity, since they are rotating in the same direction? Further, as the two bodies are separated by a minute distance, may not their magnetic forces, presumably repellant, be effective in causing their orbits to grow larger. DARWIN, POINCARÉ, and SEE have contributed to the widely accepted theory that a stellar mass rotating ever more rapidly to keep pace with decreasing diameter as a result of heat loss, may divide into two components, which continue to revolve around their center of mass in orbits growing larger and larger by virtue of tidal interactions, all operating according to NEWTON's law and the laws of friction. More recent investigators have questioned the sufficiency of tidal interactions to account for the apparent separation of the two components of a double star beyond certain limits. Might it not be well to make quantitative study of repellant magnetic forces in double-star formation and development, based upon hypothetical cases in harmony with existing knowledge concerning spectroscopic and visual double-star systems.

W. W. CAMPBELL.

May 1, 1913.

RECENT CHANGES IN LICK OBSERVATORY APPOINTMENTS.

Dr. JOSEPH H. MOORE, Acting Astronomer in the Lick Observatory, who is in charge of the D. O. Mills Expedition to the southern hemisphere at Santiago, Chile, will return to Mount Hamilton as Assistant Astronomer late in the summer f 1913. Dr. Moore has been in charge of the work in Chile during the past four years.

Dr. Ralph E. Wilson, Assistant in the Lick Observatory during the past two years, has been appointed Assistant Astronomer in charge of the D. O. Mills Expedition in succession to Dr. Moore.

Dr. Wilson and Miss Mary Adelaide Macdonald were married in the library of the Lick Observatory on May 20th. Mrs. Wilson was the first child born to parents of the Lick Observatory community, and Mount Hamilton has been her home since childhood. Dr. and Mrs. Wilson will sail from San Francisco on June 30th by the Pacific Mail S. S. "Pennsylvania" for Panama and Valparaiso.

Mr. Roscoe F. Sanford, for the past two years Assistant in the work of the D. O. Mills Expedition at Santiago, Chile, has been appointed Assistant Astronomer for longer residence in Chile. Before appointment to the D. O. Mills Expedition, Mr. Sanford was Carnegie Assistant in the Lick Observatory for two years, with residence at Mount Hamilton, and, following this term, served for three years in the Carnegie Meridian Observatory at San Luis, Argentina, as Assistant to Astronomer Tucker.

Dr. Eli Stuart Haynes has been appointed Martin Kellogg Fellow in the Lick Observatory for the academic year 1913-14, with residence at Mount Hamilton. Dr. Haynes was on the staff of the Laws Observatory, University of Missouri, for several years; during the past two years he has been a graduate student in the University of California, and during the current year an instructor on the staff of the Students' Observatory. His thesis, in completion of requirements for the degree of Doctor of Philosophy in the University of California, relates to the orbit of the minor planet 1911 *MT* (719) *Albert*. An abstract of this thesis appears in the present number of these *Publications*.

Miss Ruth Standen, Secretary of the Lick Observatory, has been granted leave of absence for six months for travel in Europe in the latter half of this year. Miss Clarice L. Davis has been appointed Secretary *ad interim*.

Dr. PAUL WILLARD MERRILL, Assistant in the Lick Observatory during the years 1909-10 and Fellow in the Lick Observatory during the academic years 1910-13, has been appointed instructor in astronomy in the University of Michigan. Dr. MERRILL'S thesis, in completion of requirements for the degree of Doctor of Philosophy in the University of California, conferred on May 14th, related to "Class B Stars Whose Spectra Contain Bright Hydrogen Lines." An abstract of this thesis appears in this number of the *Publications*, and the thesis in full will form a Lick Observatory *Bulletin*.

Dr. CARL CLARENCE KIESS, Fellow in the Lick Observatory during the academic years 1910-13, has been appointed instructor in astronomy in the University of Missouri. His thesis, in completion of requirements for the degree of Doctor of Philosophy in the University of California, conferred on May 14th, is based upon an investigation of the cluster variable, RR *Lyræ*. An abstract of the thesis appears in this number of the *Publications*, and the thesis will form the contents of a Lick Observatory *Bulletin*.

Dr. EMMA PHŒBE WATERMAN, Vassar College Fellow in the Lick Observatory during the academic year 1912-13, has been appointed assistant in the Argentine National Observatory at Córdoba. Her thesis, in completion of requirements for the degree of Doctor of Philosophy in the University of California, conferred on May 14th, consisted of a study of the visual region of spectrum in the brighter Class A stars of the northern sky. An abstract of the thesis results appears in the present number of these *Publications*, and the thesis as a whole will be published as a Lick Observatory *Bulletin*.

Mr. JOHN HIMES PITMAN, Joshua Lippincott Fellow in the Students' Observatory, University of California, during the academic year 1911-12, and Fellow in the Lick Observatory during the current year, has been appointed instructor in mathematics and astronomy in Swarthmore College.

W. W. CAMPBELL.

APPROPRIATION FOR THE LICK OBSERVATORY.

The Legislature of the State of California has unanimously appropriated the sum of $50,000 to cover the expense of construction of a three-story concrete dormitory and two frame cottages, in replacement of residence space which was destroyed by the earthquake of July 1, 1911. Expenses on account of minor damages to substantially all the buildings on Mount Hamilton, to the clocks, domes, etc., in excess of the above appropriation, have been met from other funds. The new residence space will be ready for occupation in June of this year.

W. W. CAMPBELL.

THE RIEFLER CLOCK OF THE LICK OBSERVATORY.

The Riefler sidereal clock was first mounted at the observatory in November, 1906. It was finally sealed, after rating, in June, 1907. A description of the clock, and of its performance to the end of 1907, was given in these *Publications*, volume XX, page 20.

The original lower glass cylinder, forming one of the two enclosing bells, later developed serious cracks. The most pronounced were those radiating from the metal insert, where the wires enter the case, for the electric wind, and for the chronograph connection with the break circuit. Other small cracks surround the upper edge of the bell where it rested upon the iron supporting bracket. These cracks were probably the effect of expansion and contraction of the glass and metal under temperature variation. The range of temperature in the clock chamber, in the basement of the meridian-circle building, is about 30° in the course of the year.

Since these cracks allowed entrance to air, the special design of keeping the clock under constant air pressure was defeated, and a new lower case was accordingly ordered from Munich. The new glass bell was broken in the earthquake shock of July 1, 1911, when the pendulum was thrown off its supporting carriage, and fell down through the bottom of the case; fortunately without injuring the works of the clock in any way.

Another case, ordered from the makers at Munich and delivered in 1912, had been completely smashed in transit, possibly after the box had been opened and repacked at the custom house. The glass of the larger bell, however, was extremely thin, and appeared not to have been strong enough for so heavy a casting.

Finally, a lower bell of thin copper arrived last winter, with an upper bell of glass, this last made without the broad flange of the other upper bells. In place of having a ground-glass bearing surface of 1⅛ inches, the new bell has only the natural thickness of the glass, between one-eighth and one-fourth inch. With vaseline on the edges, the closing of the case appears to be as secure as in the former case, no leakage having occurred over the range of variation of atmospheric pressure from one to four inches. The new case was put in place and the clock mounted on February, 26, 1913. The clock was rated before finally closing, on April 9th, when the air was pumped out to the amount of 100 millimeters, or four inches difference atmospheric pressure. To test the change in rate thus produced, the air was later allowed to enter, up to half this difference, then back to normal pressure; and finally the pressure was reduced 30 millimeters, giving a safe margin below the outside barometric pressure, which has a range of less than an inch in extreme cases.

The following effects on the clock rate were produced by the changes of atmospheric pressure, from free entrance of air up to the lowest amount. The first column gives the record of the inside barometer, the scale reading of which requires a correction of — 18 millimeters for the upper end of the syphon tube.

RIEFLER SIDEREAL CLOCK.

Barometer, (Uncorrected), Metric.	Barometer, Standard, Inches.	Rate of Correction.	Change in Rate— Per Mill.	Per Inch.
0.660	25.7	$+0^s.34$	.....	...
0.560	21.7	$-1\ .52$	$0^s.0186$	$0^s.47$
0.610	23.7	$-0\ .63$	0 .0178	0 .45
0.660	25.7	$+0\ .26$	0 .0178	0 .45
0.630	24.5	$-0\ .28$	0 .0180	0 .46

This change of rate corresponds closely to that predicted by the makers of the clock. The rate responds promptly to the variation in atmospheric pressure, and the change of rate appears to be the same for differences at high and low pressure, over this limited range. It would be possible to control the clock at zero rate by varying the air pressure, if the temperature remained constant. The early record of the clock showed a change in rate of 0ˢ.016 for a change of a degree Fahrenheit. This change should be investigated anew for constant pressure, and, meantime, the difference between inside and outside pressure must be kept great enough to insure the requisite pressure upon the upper bell for keeping the joint air tight.

In this connection it may be recorded that the Dent sidereal clock had formerly a temperature rate of 0ˢ.04 for one degree Fahrenheit; and that the two Höhwn clocks have not shown any direct dependence upon temperature changes. All four clocks are now well rated, and the Frodsham and Howard clocks run on Pacific standard time, by control with the rates of others.

R. H. TUCKER.

April 23, 1913.

COMET *a* 1913 (SCHAUMASSE).

The first comet of the year was discovered by M. SCHAUMASSE, at Nice, France, on the night of May 6, 1913. From observations by ANTONIAZZI at Padua, and AITKEN at Mount Hamilton, on the night of May 7th, and by HARTWIG at Bamberg on the night of May 8th, including an extreme interval of [illegible] days, we computed, by LEUSCHNER's short method, a preliminary orbit, which was sent to Harvard College Observatory by telegram on May 9th. A second orbit was computed a few days later, based upon AITKEN's measures on May 7th, [illegible], and 11th, the elements differing but little from those obtained from the shorter arc.

The comet makes its closest approach to the Sun on May [illegible] and to the Earth on May 30th. It is now visible in a small telescope and will become somewhat brighter, but will not be a conspicuous object. It is moving northwest among the stars and will be well placed for telescopic observation for several months.

C. C. KIESS.
S. B. NICHOLSON.

[illegible] 1913.

PERSONAL NOTES.

Dr. ANNA ESTELLE GLANCY, Fellow in the Lick Observatory during the academic years 1908-1910, and more recently Watson assistant in the Students' Observatory, Berkeley, has been appointed assistant in the Argentine National Observatory at Córdoba. Miss GLANCY's thesis, in completion of requirements for the degree of Doctor of Philosophy in the University of California, appears in abstract on another page of the present number of these *Publications*.

Dr. STURLA EINARSSON, who has held the position of instructor in practical astronomy in the Berkeley Astronomical Department since 1910, will continue in that position. An abstract of his thesis in completion of requirements for the degree of Doctor of Philosophy, appears on another page.

A. O. LEUSCHNER.

HONORS FOR PROFESSOR LEUSCHNER.

At the April meeting of the Board of Regents of the University of California Professor A. O. LEUSCHNER of the Berkeley Astronomical Department was appointed Dean of the Graduate School.

Professor LEUSCHNER was elected a member of the National Academy of Sciences at its semi-centennial celebration, April 22d-25th.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these Publications, and the Publication Committee has acted favorably upon the suggestions.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

Researches on the Motion of the Moon, by Simon Newcomb.[1]

This work, which has recently been distributed, contains the final memoir prepared by the late Professor Newcomb, the copy for the printer having been completed only a month before his death. It is a continuation of the author's former memoir on the Moon's motion, which was published as an appendix to the Washington observations for 1875. In the preface to the present volume it is stated that "the whole work may be described as a discussion of ancient and mediæval eclipses of the Sun and Moon, and of occultations of stars by the Moon observed from 1627 to the present time, with the general purpose of studying those fluctuations in the Moon's motion which are not represented by existing theory."

"The most important fact," Newcomb says, "brought out by this and other researches of the author on this subject, and by a comparison with the theoretical researches of other investigators, especially of Professor Ernest W. Brown, is that the Moon's mean motion is subject to fluctuations which are not only unrepresented by existing theory, but for which it seems difficult to assign any sufficient physical cause."

The main purpose of the present memoir is "to show with all the precision of which the observations admit, what unexplained fluctuations the mean motion of the Moon has actually undergone." The observations are, principally, those of occultations of stars by the Moon, and the method of investigation is, in brief, the comparison of the Moon's positions as deduced from these observations, with those derived from Hansen's tables, after the latter have been corrected to reduce them to the "provisionally accepted theory." This comparison gives the data from which equations of condition are formed, whose solution gives the deviations from theory of the Moon's mean motion in longitude. The account of the methods and formulæ of reduction adopted, of the corrections to Hansen's tables, and of the data relating to the original observations is followed by chapters giving the corrected tabular positions of the Moon, the positions of the occulted stars, the position-angles used in computing the coefficients of the equations of condition, and these equations in full. The final chapters are then given to a discussion of the results obtained from the solution of the equations combined with the results from the author's earlier investigations.

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[1] Volume IX, Part I, of the "Astronomical Papers," prepared for the use of the *American Ephemeris and Nautical Almanac.*

The principal conclusion reached is that "there is no value which we can assign to the Moon's undisturbed mean motion as definitive." There are fluctuations which cannot as yet be explained. "So long as they might be supposed to arise from defects in the computations of gravitational theory we might plausibly suppose them to arise from actual periodic terms which had eluded our scrutiny. But today it seems almost as certain as any proposition in mathematical science can be that there are no known masses of matter, the gravitational action of which could produce the observed effects. Working quite independently of each other, I feel that Brown and I have examined every possible term and made such estimation of its limiting possible magnitude as to insure the correctness of our conclusions. Brown has gone yet further by finding the limiting value of any possible omitted term to be insensible."

The expression for the great fluctuation is given by Newcomb as,—

$$\delta v = 12''.95 \sin\,[1^\circ.31\,(t - 1800.0) + 100^\circ.6]$$
Period = 275 years.

Superimposed upon this are smaller fluctuations.

The author closes his "concluding remarks" with these sentences: "The most unsatisfactory feature of the conclusion of the entire work as carried through by the author is that, until the matter is cleared up, it will be impossible to predict the Moon's mean longitude with the precision required for astronomical purposes. We shall be obliged to correct the Moon's mean longitude from time to time, perhaps at intervals of 10 or 20 years, from observations."

Dr. FRANK E. ROSS was Professor NEWCOMB'S associate in carrying out this investigation, acting both as computor and as superintendent of computations. R. G. AITKEN.

May, 1913.

THE MASS OF THE NUCLEUS OF HALLEY'S COMET.

In a paper published in the *Bulletin of the St. Petersburg Academy*, 1913, No. 5, Professor S. ORLOFF gives an interesting investigation of this question, based upon photometric observations. Just as we have a phase effect in the light from the Moon, so also if the nucleus of a comet consists either of a single mass or of a swarm of small material particles, it should show a phase effect depending upon its position with reference to the Sun and to the observer. Earlier investigations by the same author have shown the existence of a phase effect in the nucleus of Halley's Comet, and in the present paper ORLOFF makes the attempt to separate from all the light proceeding from the nucleus that portion which may be due solely to the reflected rays of the Sun, depending upon the phase angle and upon the distances of the comet from the Earth and the Sun respectively (Δ and r).

Besides this reflected light, the nucleus may give out intrinsic light of its own, as a secondary effect of the action of the solar rays.

For the reflected rays the law of diminution of brightness is—

$$\frac{X}{a\Delta^2 r^2},$$

where a is the correction for phase; for the calculation of this factor ORLOFF used tables derived according to LAMBERT'S theory. For the diminution of the intrinsic light of the nucleus, the law is, of course, unknown, but may be expressed by the formula,—

$$\frac{Y}{\Delta^2 r^n},$$

where the exponent n is unknown, and must be so determined as best to satisfy the observations. The observed brightness of the nucleus H_1 may then be represented as the sum of the reflected and the intrinsic light in the form,—

$$\frac{X}{a\Delta^2 r^2} + \frac{Y}{\Delta^2 r^n} = H_1.$$

Each individual observation gives, accordingly, one equation with the three unknowns, X, Y and n, to be solved by least squares. Before the passage of Halley's Comet through perihelion the influence of phase was negligible, amounting to only 0.18 magnitude; thirty observations by BEMPORAD were selected for the investigation, taken in the epoch from May 24 to July 4, 1910, after the passage of the comet across the Sun's disk. The solution gave,—

$$X = 5.717 \text{ and } Y = 0.072.$$

An inspection of the relative magnitude of these quantities shows at once that the nucleus shone only by reflected light, the amount of intrinsic light being negligible. Another solution showed that it was impossible to neglect the effect of phase.

The investigation showing that the nucleus shone simply by reflected sunlight like a star of magnitude 7.2, it becomes possible to compute the mass of the nucleus; here three assumptions are necessary:—

1. Concerning the magnitude of the nuclear particles;
2. Concerning the albedo of these granules;
3. Concerning their density.

For the albedo ORLOFF takes 0.2 (*Mars* = 0.22), and for the density of the particles he takes the mean density of the Earth. If the nucleus were one solid mass, a maximum value of the mass is obtained; postulating, on the other hand, that it is made up of small particles of not less than 2^{mm} radius, a minimum value is obtained (if particles were smaller than this, the influence of light pressure would be greater than 0.0001 of gravitation, and marked perturbative effects would be noticed in the orbit of the comet). It is possible to affirm with some certainty that the mass of the nucleus is included between the two limits thus given. ORLOFF'S results are (Earth's mass = 1):—

$$\frac{1}{2\cdot 10^{14}} < \text{mass of nucleus} < \frac{1}{6\cdot 10^{5}}$$

Either value is probable and possible, but everything leads to the belief that the smaller value is more likely to be nearer the truth, and it is not improbable that the true mass of the nucleus of Halley's Comet may be much less even than this. This minimum mass amounts to about thirty million tons, equal to less than six cubic miles of air at sea level density.

H. D. CURTIS.

THE ORBIT OF β CORONÆ BOREALIS ($15^h 23^m.7$).[1]

An unusual circumstance attends the determination of the orbit of *β Coronæ Borealis*, which has been observed during 1910-1912 at the Dominion Observatory in Ottawa, Canada. The star's spectrum is given in the *Annals* of Harvard College Observatory as "F peculiar," with the note that "this star is very peculiar in the relative intensity of the solar lines." Mr. J. B. CANNON, who measured the plates and determined the orbit, says that the lines are so different from those of a solar standard plate that the comparator measures were very unreliable. Consequently all plates were measured with respect to a single plate of the star itself and the latter plate was given the best measurement possible on the comparator against the solar standard. A consecutive plot of observations gave evidence of an oscillating amplitude of velocity. The period of this oscillation is 400.8 days, while the period of the simple velocity oscillation is 40.9 days. The range of the variation of amplitude is $4^{km}.8$. A sine curve was assumed for the long oscillation and the values given by it applied to the velocities obtained from the different plates in order to get a curve for the short period and to use all the observations in the determination of this curve. Fourteen normal places were formed and the elements were derived by the graphical methods only, since the accuracy of the measures was not sufficient for further reduction. The eccentricity 0.4 is quite large. The sine curve of the short period cannot be considered well defined. The amplitude is $6^{km}.2$, which is not much greater than that of the long period. The probable error of an average observation is $2^{km}.6$, which is greater than the semi-amplitude of the long period. The probability of the variation of amplitude would seem to depend upon its apparent periodicity and the reduction of residuals to reasonable size. G. F. PADDOCK.

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[1] *Journal of the Royal Astronomical Society of Canada*, 6, 343, 1912.

THE DETERMINATION OF THE CLASS OF THE SECONDARY SPECTRA OF ALGOL VARIABLES.

In Dr. SCHLESINGER'S discussion of spectroscopic binaries,[1] he says there was at that time no definite evidence of a difference of spectrum between the primary and secondary components of first-type stars. But, of course, at that time few secondary spectra had been observed. Moreover, if the difference of magnitude exceeds a magnitude, the secondary spectrum is usually invisible. It has recently been found by Mr. HARLOW SHAPLEY[2] that several *Algol* variables, which would undoubtedly be shown to be spectroscopic binaries if spectrographs were able to secure the spectra of such faint stars, have considerable difference of spectrum between their primary and secondary components. His method depends upon certain facts which he has derived from the study of *Algol* systems. The radius of the secondary is in general greater than that of the primary. Since the majority of systems have nearly equal masses, the greater volumes of the secondary components indicate low densities. Assuming equal masses in thirty-five systems whose primaries have spectra of classes B and A, the average density of the primary components is one seventh (or less) that of the Sun; that of twenty-nine secondary components whose spectra are to be determined is less than one thirtieth that of the Sun. In consequence of the larger size of the secondary, many systems present total eclipse of the primary during minimum phase. The light is then entirely that of the secondary. If the latter were bright enough and the observation long enough the spectrum of the secondary could be directly obtained. But the duration of eclipse is too short except in a few cases. However, the color index, which is the difference between the visual and photographic magnitudes, may be found by determining the photographic and visual magnitudes at minimum brightness, or by determining the photographic and visual range of brightness. SHAPLEY thus determines the color index at minimum for two systems whose primaries are of Class A: for Y *Piscium* 0.35 magnitudes, which, according to KING'S[1] scale of color-indices and spectral class, puts the secondary in the spectral Class F0; for RR *Draconis* 0.84 magnitude, which puts the secondary in the spectral Class G4. Among spectroscopic binaries, the fainter component is the less massive. This fact and the fact of extremely low density would seem to indicate less age for the secondary than for the primary. But the later class of the secondary spectrum as found for the *Algol* variables above mentioned would seem to indicate greater age. The determination of secondary spectra is consequently important in the study of the development of close binary systems. G. F. PADDOCK.

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[1] *Allegheny Publications*, I, 142.
[2] *Astrophysical Journal*, **37**, 154.

THE RANGES OF VELOCITY AND BRIGHTNESS OF CEPHEID VARIABLES.

A significant point concerning *Cepheid* variables has recently been brought to notice by LUDENDORFF of Potsdam, who has published a note in the *Astronomische Nachrichten*[2] giving the list of known *Cepheid* variables and pointing out an apparent connection between the ranges of magnitude and of radial velocity variation. δ *Cephei* has the maxima of ranges, 0.88 in magnitude and 40^{km} in velocity. *Polaris* has the minima of ranges, 0.12 in magnitude and 6^{km} in velocity. The others increase from about a half to a whole magnitude and from 15^{km} to 50^{km}. The relation is roughly linear, expressed by the equation $2K = 47.3A$, in which K is the semi-amplitude of the radial velocity curve and A the range of magnitude. To a variation of one magnitude corresponds a range of radial velocity of about 47^{km}. A plot shows the observations to fal' more or less along a straight line through the origin inclined about 30° to the axis of magnitudes.

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[1] *Harvard Annals* [illegible], 180.

[2] [illegible] *Nachrichten* [illegible], [illegible]

LUDENDORFF's conclusion is that the relation is not definitely proved, but that if proved in the future, it will be possible to compute the spectroscopic orbit from the light curve; and also that one can scarcely avoid the impression that the spectral line shifts are due to some other cause than radial velocity.

The latter part of this conclusion, however, may be quite unnecessary; for, if the above relation between amplitude of oscillation and range of magnitude actually exists, it may be a function of the inclination of the orbit plane. It is well known that the greatest brightness of *Cepheid* variables occurs during the interval in which the body is supposed to be approaching the Sun. If the increase of brightness is due to a greater amount of light emitted by the advancing hemisphere, then the amount of variation of brightness visible from the solar system depends upon the inclination of the orbit plane to the line of sight. The variation of both magnitude and radial velocity would be zero if the orbit plane is perpendicular to the line of sight and greatest if the orbit plane passes through the line of sight. If, then, DUNCAN's theory[1] be true, the relation just discovered is really a relation between the range of magnitude and the inclination of the orbit plane, so that the latter may perhaps be determinable from the former.

G. F. PADDOCK.

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[1] *Lick Observatory Bulletin*, V. 87.

GENERAL NOTES.

The minutes of the fifteenth meeting of the Astronomical and Astrophysical Society of America, held at Cleveland, December 31, 1912, to January 2, 1913, are printed in *Science* for April 25, 1913. Abstracts are given of the thirty-six papers read at the meeting.

Two important papers dealing with the distribution of stars in space were read by Messrs. DYSON and EDDINGTON at the meeting of the Royal Astronomical Society of London, held on March 14, 1913. Mr. DYSON's paper treated the stars in CARRINGTON's circumpolar catalogue, Mr. EDDINGTON's the bright stars. Abstracts of these papers will be given in our next number.

The *Observatory* reports that the transfer of the Solar Physics Observatory to Cambridge University took place on April 1, 1913. The staff is constituted as follows: Director, H. F. NEWALL; assistant director, F. J. M. STRATTON; observer in meteorological physics, C.T.R. WILSON; senior observers, F. E. BAXANDALL and C. P. BUTLER; junior observers, W. E. ROLSTON and W. MOSS.

Some idea of the important work being done by the Royal Astronomical Society of Canada in promoting a general interest in the science may be gained from the account of the annual meeting printed in the January-February, 1913, number of the *Journal* of the society. The society has 421 active members distributed among seven centers. At each center regular meetings have been held, varying in number from twenty-one at Toronto to six or seven at some of the smaller centers. Some of these meetings—particularly at Ottawa—are devoted to the presentation and discussion of technical papers, the others to the presentation of more popular accounts of recent progress in astronomy and related sciences, not only by active members of the society, but also by visiting scientific men.

Director FRITZ COHN, of the Kgl. Astron. Rechen-Institut, Berlin, has issued a circular letter proposing a plan for co-operation in the systematic observation of the minor planets. A complete translation of the letter is printed in *Popular Astronomy* for May, 1913. For the observation of the known asteroids, it is suggested that the existing organization of photographic observers, now including five stations, be enlarged, and that the visual observers also organize and distribute among them the various objects, with the aid of the central station (the Rechen-Institut) in such a manner as to insure the adequate observation of each object, while preventing unnecessary duplication of measures. In general two or three measures of a known asteroid suffice to provide the data needed for orbit correction.

The newly discovered planets require somewhat more attention. They are usually discovered by photography and, in general, will be faint objects. Discovery should be promptly announced and the announcement sent by the central station to the visual observers; or, when feasible, by the discoverer to some visual observer direct (M. WOLF now sends such announcements to MM. PALISA and JAVELLE). Five or six accurate visual observations distributed over a period of from six to eight weeks are needed as the basis for a good orbit.

The Rechen-Institut is prepared to act as a central station and to give all possible assistance by furnishing lists of planets in need of observation and ephemerides when desirable, and by computing necessary orbits.

It is to be hoped that the proposition can be put into execution, for at the present time some asteroids are observed more often than necessary, while many others are neglected, and some, through neglect, are lost.

It is with regret that we record the death, early in April of this year of F. M. RISTENPART, director of the National Observatory, Santiago, Chile.

The following notes have been taken from *Science:*

The National Academy of Sciences celebrated the semi-centennial anniversary of its foundation on April 22d, 23d, and

24th, exactly fifty years after its first meeting. It was a most successful meeting, with the largest attendance of members in the history of the academy. There was no program of technical papers, but in its place a series of addresses. Dr. Ira Remsen, the president of the academy, at the first session read an address on the history of the academy, and then introduced President Arthur T. Hadley, of Yale University, who spoke on "The Relation of Science to Higher Education in America." He was followed by Dr. Arthur Schuster, secretary of the Royal Society of London, who spoke on "International Co-operation in Research." At the afternoon session Dr. George E. Hale, director of the Mount Wilson Solar Observatory, gave an address on "The Earth and Sun as Magnets." On the morning of the following day, Dr. J. C. Kapteyn, director of the Astronomical Laboratory of the University of Groningen, gave an address on "The Structure of the Universe." Dr. Theodor H. Boveri, of the University of Würzburg, was to have spoken on "The Material Basis of Heredity," but was unable to be present owing to ill health. The Watson medal for astronomical research was presented to Dr. J. C. Kapteyn, the Draper medal for astrophysical research to the French Ambassador for M. Henri Deslandres, the Agassiz medal for oceangraphical research to the Norwegian minister for Dr. Johan Hjört, and the Comstock prize of the value of $1,500 for research in radiant energy, to Professor R. A. Millikan, of the University of Chicago.

The adjudicators of the Adams prize of the University of Cambridge report that the two essays submitted to them with the following titles are of distinction: "The Theory of Radiation," by Mr. S. B. McLaren, and "The Fundamental Spectra of Astrophysics," by Dr. J. W. Nicholson, between whom the prize is divided in equal shares.

At a meeting of the electors to the Plumian professorship of astronomy in the University of Cambridge, held on April 19th, Mr. A. S. Eddington, chief assistant at the Royal Observatory, Greenwich, was elected to the professorship, in succession to the late Sir George Darwin.

Mr. A. R. Hinks, F.R.S., chief assistant at the Cambridge University Observatory, has been appointed Gresham professor of astronomy, London, in succession to the late Mr. S. A. SAUNDER.

A tablet in honor of Dr. SAMUEL PIERPONT LANGLEY was unveiled in the Smithsonian Institution on May 6th. Addresses were made by Dr. ALEXANDER GRAHAM BELL and Dr. JOHN A. BRASHEAR.

MINUTES OF THE MEETINGS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT THE STUDENTS' OBSERVATORY, IN BERKELEY, ON APRIL 11, 1913.

Two meetings of the society were held on this date, the first at 3:00 P. M. and the second at 8:00 P. M. Both were programmed as features of the third annual session of the Pacific Association of Scientific Societies, of which the Astronomical Society is a constituent member. The annual sessions of the Pacific Association had been called for the 10th, 11th and 12th days of April, 1913.

The scientific program for the Astronomical Society was arranged by Professor A. O. LEUSCHNER, director of the Students' Observatory, and to him is due the credit for a day of unusual interest and pleasure to the members and friends of the society.

The afternoon session was called to order at 3:00 P. M. by President ALEX. G. MCADIE, and the following papers were presented and (with one exception) read by their authors, the reading in each case being followed by a general discussion by all present:—

"A Plea for More Amateur Variable-Star Observers," by EDWARD GRAY, of Eldridge, Cal.

"The Davidson Zenith and Transit Telescope," by OSCAR W. LANZENDORF.

"The Cluster Variable RR *Lyræ*," by CARL CLARENCE KIESS.

"Class B Stars Whose Spectrum Contain Bright Hydrogen Lines," by PAUL WILLARD MERRILL (read by Mr. EINARRSON).

"The Visual Region of Spectrum in Brighter Class A Stars," by EMMA PHŒBE WATERMAN.

At this point in the proceedings the meeting adjourned to attend in a body the reception which had been courteously offered by the President of the University and Mrs. WHEELER to all members of the Pacific Association of Scientific Societies. A pleasant half hour was spent in the presidential mansion and its hospitality gratefully appreciated. An opportunity, at the same time, was given to members to meet the representatives of other societies attending the sessions.

At 6:30 many of the members dined together at the Hotel Cloyne Court, on the Ridge Road, and it was noticed that the contemplation of celestial things did not seriously interfere with their enjoyment of a very substantial and daintily served meal.

At 8:00 P. M. the meeting was again called to order in the lecture-room of the observatory and the program of the afternoon was continued by the presentation of the following papers:—

> "A Double Star Survey," by Dr. Robert G. Aitken, of Lick Observatory.
>
> "A Comparison of Photographic, with Theoretical Positions of Minor Planets: (105) *Artemis,* (115) *Thyra,* (119) *Altheca,* (133) *Cyrene,* (139) *Juewa,* (174) *Phædra,*" by Anna Rodman Kidder.
>
> "The Orbits of the Minor Planets (624) *Hector,* and (588) *Achilles* of the Trojan Group," By Sturla Einarrson.
>
> "The Orbit of the Minor Planet 1911 *MT,* (719) *Albert,*" by Eli Stuart Haynes.
>
> "On von Zeipel's Theory of the Perturbations of the *Hecuba* Group of Minor Planets," By Anna Estelle Glancy.

With the exception of the paper by Dr. Gray at the afternoon session and that of Dr. Aitken in the evening, it is of special interest to note that all of the foregoing papers were prepared by students or fellows in the Astronomical Department of the University of California. It was the original intention of Professor Leuschner to occupy most of the time at the evening session with a lecture of his own on "The Work of a Students' Observatory," but, finding that time was not sufficient, he generously gave way to his brilliant pupils. The exposition was one to stir a teacher's pride, and Professor Leuschner did not fail to recognize it in a few words of personal commendation for each student, which must have warmed the cockles of their hearts.

The lecture on "The Work of a Students' Observatory," which was to have been given in commemoration of the twenty-fifth anniversary of the establishment of the Students' Observatory in Berkeley, is promised by Professor Leuschner for a later date. It was frankly conceded, however, both by Professor Leuschner and all present, that the work of a students' observatory spoke for itself in the fine work of the young men and women whose papers had been read during the day.

Among those present at these meetings were: Dr. W. W. Campbell, director of the Lick Observatory; Dr. S. D. Townley, of Stanford; Charles Burckhalter, director of Chabot Observatory; Professor R. T. Crawford, of the Students' Observatory; Mr. Charles S. Cushing, Mr. F. V. Cornish, Professor George C. Edwards, and many others.

Altogether the occasion was a notable one in the history of the society and most stimulating to those who take an interest in astronomy.

D. S. Richardson,
Secretary.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD AT STUDENTS' OBSERVATORY, BERKELEY, ON APRIL 11, 1913, AT 7:30 P. M.

President McADIE in the chair. Other Directors present were AITKEN, TOWNLEY, CRAWFORD, CUSHING, MARKWART, CORNISH and RICHARDSON.

The minutes of the last meeting, as printed in the Publications, were approved.

Application for life membership in the society was received from Mr. JAMES D. MADDRILL and favorably acted upon by unanimous vote.

The following report of the Finance Committee was received and approved.

SAN FRANCISCO, CAL., February 7, 1913.

The President and Board of Directors, Astronomical Society of the Pacific.

GENTLEMEN: Pursuant to a resolution of your Board, passed at the meeting of January 25th, 1913, authorizing the Finance Committee, in conjunction with the President, to invest two or three thousand dollars of the banked funds of the society in interest-bearing bonds of proved security, your committee begs to report as follows:—

Under date of February 4th, 1913, it purchased, through the house of Rollins & Sons, of this city, three General Mortgage Gold Bonds of the Los Angeles Gas & Electric Company, numbered respectively 712, 713 and 714. These bonds, which are of the par value of $1000.00, bear interest at 5%, payable on the first days of January and July and mature on July 1st, 1934.

The price paid was $996.25 per bond which, with accrued interest up to and including February 4th, and commissions to brokers, gave a bill of $3,012.50, as follows:—

3 bonds @ $996.23	$2988.75
Interest to Feb. 4th	16.25
Commissions	7.50
	$3012.50

The bonds have been apportioned among the various funds as follows:—

Bond No. 712 to Life Membership Fund.
One half of Bond No. 713 to the William Alvord Fund.
One half of Bond No. 713 to the John Dolbeer Fund.
One half of Bond No. 714 to the Library Fund.
One half of Bond No. 714 to the Bruce Medal Fund.

Your committee begs to further report that it has secured, through the firm of Rollins & Sons, the following statement showing the present market values of bonds held by the society:—

Two Oakland Transit Cons. 5s, due July 1, 1932	$ 2,040.00
Two So. Pac. Coast Ry. 1st Mtg. 4s, due July 1, 1937	1,840.00
Three Sunset T. & T. Cons. 5s, due October 1, 1929	3,120.00
Three C. C. Water Co. 1st Mtg. 5s, due July 1, 1915	2,985.00
Two Edison Elec. Co. of L. A. 5s, due Sept. 1, 1932	2,040.00
Two Bay Cos. Pow. Co. 5s, due Sept. 1, 1933	2,030.00
Total	$14,055.00

The cost of the above mentioned securities to the society was as follows.—

Two Oakland Transits	**$ 2,080.00**
Two So. Pac. Coast Ry.	**2,000.00**
Three Sunset T. & T.	**3,252.06**
Three C. C. Water Co.	**3,106.50**
Two Edison Elec. Co.	**1,954.44**
Two Bay Cos. Power Co.	**2,025.00**
Total	**$14,418.00**

It will be seen that if these bonds are held by us until maturity the original premiums paid by the society will be wiped out and a future deficit must result. Accepting the schedule of Rollins & Sons as correct, the present depreciation is as follows:—

On Oakland Transits	**$ 40.00**
On Sunsets	**132.00**
On C. C. Water Co	**121.50**
Total	**$293.50**

It will be noticed that the depreciation in the bonds of the South Pacific Coast Ry. is not considered here because the society purchased them at par. In the case of the Edison Electric Co.'s bonds and those of the Bay Counties Power Co., both of which, according to the Rollins schedule, have appreciated in value since purchase by the society, the former were secured at a little less than par and the latter at a little over.

With a view to meet this situation gradually and avoid any embarrassment to the accounts of the society which might arise from any of the bonds being called in, or which might result if they were all permitted to mature before charging off the premiums, the Treasurer has been instructed to accept the valuations as given by Rollins & Sons and to charge off on his accounts for the current fiscal year ten per cent of the recognized depreciation on the Oakland, Sunset and C. C. Water Co.'s bonds.

Respectfully submitted,

Chas. S. Cushing,
A. H. Markwart,
Finance Committee.

There being no other business, the meeting adjourned.

D. S. Richardson,
Secretary.

OFFICERS OF THE SOCIETY

Mr. Alex. G. McAdie	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. R. T. Crawford	*Second Vice-President*
Mr. J. Costa	*Third Vice-President*
Mr. D. S. Richardson	*Secretary-Treasurer*
Mr. R. G. Aitken	*Secretary on Mount Hamilton*

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Finance Committee—Messrs. C. S. Cushing, W. H. Crocker, A. H. Markwart.

Publication Committee—Messrs. R. G. Aitken, H. D. Curtis.

Library Committee—Messrs. D. S. Richardson, J. Costa, A. H. Markwart.

Comet-Medal Committee—Messrs. W. W. Campbell, S. D. Townley, H. D. Curtis.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

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PUBLICATIONS
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Vol. XXV San Francisco, California, August, 1913 No. 149

THE PRESENT STATUS OF THE PROBLEM OF STELLAR EVOLUTION.

By E. Phœbe Waterman.

Stellar evolution—the order of development of worlds so huge and so remote that the mind fails utterly to realize their dimensions, the laws of a progress so slow as to be beyond detection in any individual case—this is one of the problems which astronomy has set itself to solve. And the attempt is not so audacious, nor the solution so impossible, as might at first appear. Many lines of research once seemingly unrelated and independent are now seen to be convergent, some have already merged. Attempts at correlation have become increasingly numerous of late and are passing from the realm of conjecture into that of reality. Such, for instance, is the close relationship of spectral class with color index, and with radial velocity.

The advance upon the problem has been rapid enough in the past few years that it is not unprofitable to assemble the facts now at hand, take note of the position already reached, and inquire as to the outlook. What are the points of attack? What data have we upon which to base a discussion of the question? In this connection, we find the following investigations in progress, or completed at the present time: the classification of the spectra of the stars; the origin and sequence of the spectral lines of these classes; the variation in wave-length of certain lines with change in class; color index, or the difference between the visual and photographic magnitudes of stars; stellar temperatures and intrinsic brightness; proper motions, parallaxes, and absolute magnitudes; radial velocities; spectroscopic binary systems; star drifts.

In the spectra of the stars we have, obviously, a means of determining differences among them. Could we obtain spectra of high enough dispersion, and could we interpret the phenomena we find, there is little which we could not read off, from its spectrum, of the constitution of a star and of the conditions prevailing in its atmosphere. A thorough-going classification of stellar spectra is accordingly one of the first points of attack in the problem.

The great majority of stellar spectra fall into four well-marked groups, first defined by SECCHI,[1] well-marked as to their general characteristics but forming a sequence by the blending of one group imperceptibly into the next—except in the case of Type IV, between which and Type III the transition is not so evident. We have first the spectra of the simplest type, with a continuous spectrum marked by absorption lines of hydrogen only, or of hydrogen and helium. These merge, through the gradual increase in strength of the metal lines, into spectra of Type II, wherein the metals predominate. These in turn give way to bands or flutings indicative of chemical combination among the elements of the stellar atmosphere. Two sorts of flutings appear, differing in source, and marking Types III and IV. Aside from these spectra, we have a fifth type, suggested by PICKERING—spectra in which the continuous background is marked by broad and faint bright bands, most of which coincide with the lines of hydrogen and helium. We have also the spectra of nebulæ, of which but little is known as yet, and the spectra of the Wolf-Rayet stars marked by both bright and dark lines. Recent classifications, notably those of Harvard[2] and of LOCKYER,[3] are more detailed and inclusive than SECCHI's. They do not, however, run counter to it, nor to one another in the matter of group boundaries; but they do differ as to the order in which these groups shall follow one another, as, whether the helium stars (Harvard B) shall fall near the beginning or near the middle of the evolution curve. The question here becomes co-extensive with that of evolution itself, and, in discussing it further, we need the data supplied by the other lines of research.

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[1] Outline given, YOUNG. "General Astronomy."
[2] *Harvard Annals*, **28** (II), 135, 1901.
[3] *Philosophical Transactions*, **184** (A), 675, 1892.

Laboratory research gives us much valuable information as to the origin of the spectral lines marking these classes and the interpretation of the differences in behaviour to be observed among them. As our knowledge of the laboratory conditions producing these differences grow, we can proceed to a tentative statement as to the conditions which prevail in stellar atmospheres. Take, for example, the nature of the enhanced line, and the conditions of temperature, pressure, and electrical intensity governing its appearance. What is the enhanced line, and what does its presence in a spectrum imply? As is well known, the spectrum of an element as seen in the electric spark differs considerably from that obtained in the arc, both in the wave-lengths of the lines present and in their relative intensities. The difference may be stated as follows:[1] Suppose we photograph the spectrum of, say, the titanium arc. Suppose next, we photograph the same region of the spark spectrum, giving it such an exposure that most of the lines will be equal in intensity to the lines in the arc spectrogram. Comparison of the two plates will show that in the spark spectrum there are strong lines present which are very faint or wanting altogether in the arc spectrum. Such lines as are relatively strengthened in the spark spectrum are called "enhanced" lines. The presence of the enhanced lines of the metals in a star's spectrum indicates that the conditions prevailing in the stellar atmosphere differ in certain essentials from those prevailing in other stars whose spectra show, not the enhanced, but the arc, lines of these metals. What the essentials are, we are coming to know more and more definitely.

That enhanced lines are perhaps dependent slightly upon temperature, and to a much greater extent upon electrical conditions, has been shown by KING[2] in his experiments with a thin-walled electric furnace. Again, the shift of enhanced lines relatively to arc lines has been investigated by GALE and ADAMS.[3] Particularly significant, along a different line of laboratory research, is FOWLER's success in obtaining a new hydrogen series[4] (at least one line of which is one hitherto unidentified line in stellar spectra), as being another step forward in the task of reproducing in the laboratory the conditions existing in the stars.

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[1] *Lick Observatory Bulletin*, IX.
[2] *Astrophysical Journal*, **37**, 119, 1913.
[3] *Astrophysical Journal*, **35**, 10, 1912.
[4] *Monthly Notices Royal Astronomical Society*, **73**, 62, 1912.

The thorough study of solar conditions now in progress at many stations is illuminating in the application of its results to stellar spectra. In the chromosphere are found the lines characteristic of stars from Classes B to F, helium, hydrogen and the enhanced lines of the metals.[1] In the spectrum of sun-spots, on the other hand, is found a close analogy to stellar spectra of Class K[2]. The possibilities here suggested for the interpretation of stellar conditions from the detailed study of these spectra on the large scale which is now possible is enormous.

Closely allied to these investigations is the variation in the wave-lengths of many stellar lines, detected by Albrecht.[3] Great numbers of stellar lines, on the scale usually employed, are in reality blends of two or more components. These components differ from one another in source, intensity and character, and with changing conditions in the stars they naturally change differently, possibly even in opposite directions and to the extent that one shall almost disappear while another increases greatly in intensity. The effect upon the apparent stellar line is to shift its center in the direction of the strengthening component. The shift is measurable, and evidently furnishes another criterion whereby we may judge of the conditions prevailing in each star. Curves obtained by platting wave-length against spectral type, on the assumption that the intervals F to G, G to K, K to M, are equal, check the value of these intervals, and justify the assumption. Again, "comparison with sun-spot lines indicate strongly that physical conditions as we pass from F to the M type vary roughly in the same direction as from the Sun to sun-spots." We shall refer to this again.

Parkhurst and Jordan[4] have followed up a different line of attack, opened by Pickering in the Harvard Photometry,[5] through their investigations, by photographic methods, of the visual and photographic magnitudes of stars. By means of plates sensitized for the visual rays, and with the exercise of proper precautions, they arrive at visual magnitudes which, compared with visual and photographic magnitudes found at Harvard, Potsdam, and Greenwich, show systematic differences, but a reasonable degree of agreement." The two series, taken one upon red-sensitive and the other upon ordinary plates, furnish "a practically simultaneous determination of visual and photographic magnitudes free from most of the uncertainties of visual methods." Moreover, "definite color intensities (i. e., the difference between visual and photographic magnitudes), correspond in general to definite spectral types. While this may or may not give us much information as to stellar conditions in specific cases, it does furnish "a possible method of determining the spectrum of stars too faint for the ordinary telescope." It offers also an independent check upon the values of the spacing of the Harvard classes, with which the color intensities are compared.

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[1] *Lick Observatory Bulletin*, Thesis, P. W. Merrill and E. P. Waterman.
[2] *Astrophysical Journal*, **30**, 86, 1909; **24**, 69, 1906.
[3] *Astrophysical Journal*, **24**, 333, 1906; **33**, 130, 1911.
[4] *Astrophysical Journal*, **27**, 169, 1908; **36**, 169, 1912.
[5] See, *Lick Observatory Bulletin*, **6**, 125, 1910.

The question of stellar temperatures is another fairly new and promising line of investigation. WILSING,[1] HEPPERGER,[2] NORDMANN,[3] and ROSENBERG[4] have each published a series of temperatures for the stars relative to that of the Sun. These determinations are not yet as satisfactorily established as is desirable, but they are in fair agreement among themselves, and in entire harmony with the sequence of temperatures derived by ADAMS from the comparison of stellar and sun-spot spectra, by ALBRECHT, and by LOCKYER from the relative strength of enhanced and arc lines in stellar spectra. The absolute temperatures derived have been based in each case upon measures made with a photometer or from the spectrum, of the difference in the intensities of the red, yellow and blue light emitted by the stars. From these differences, expressed in magnitudes and reduced to the Sun as standard, are derived temperatures relative to that of the Sun. NORDMANN goes farther, and investigates the intrinsic brightness of these stars, deriving an upper limit for the value of the absorption of radiation in their atmospheres from that of the absorption in the solar atmosphere. Another method of finding the density of stellar atmosphere has been applied by ADAMS[1] to some of the brightest stars. It is based upon the difference already referred to, in the shift under pressure of arc and enhanced lines, a definite relative shift corresponding roughly to a definite pressure. Through measures of spectra of unusually high dispersion, it was possible to detect a difference in shift between the two sets of lines, upon which to base an estimate of the pressures prevailing in the atmospheres of these stars. A comparison of results from the two methods is unfortunately impossible since the same stars were not used in the two investigations.

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[1] *Astrophysical Journal*, **32**, 130, 1910.

[2] *Wien. Sitz. Ber.*, **118**, 2a, 197, 1909.

[3] *C. R.* **149**, 557, 1038, 1909; **150**, 669, 1910.

[4] *Astronomische Nachrichten*, **193**, 358, 1913.

The outlook in the field of parallaxes and absolute magnitudes is not so promising. The direct determination of parallax is beyond the limits of our instruments at present, except in the case of a comparatively small number of stars, and the data here is meager. From the absolute magnitudes of those stars whose parallax is known, the existence of two great divisions in the stars is suspected by HERZSPRUNG, one of stars of high and the other of low intrinsic brilliancy, and named by him "giant" and "dwarf" stars. Too many inferences should not be drawn from these results until they have been confirmed by many more facts. A recent paper by RUSSELL[2] gives an optimistic statement of the outlook, however.

The increase of peculiar radial velocity with advance in type is now well established by the work of CAMPBELL,[3] the peculiar radial velocity being the velocity after correction for the Sun's motion through space has been made. As we progress from Class B through A, F, G., and K to M, we find the average velocity for the class increasing steadily, from 6^{km} per second for B to 17^{km} for M. Planetary nebulæ rank even higher, with an average of 25^{km} (the results of visual observations made by KEELER). The great nebula in *Orion*, on the other hand, in contrast with the planetary nebulæ, were found to have a (peculiar) radial velocity differing but little from zero. The character of its spectrum, together with the fact that large nebulous areas are associated with stars of Classes O, B, and A, never with Classes G, K, M, and N, confirms the placing of these unformed nebulæ at the beginning of the evolution scheme. Peculiar radial velocity seems to offer a definite means of fixing the place of a star in the scheme of evolution.

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[1] *Astrophysical Journal*, **33**, 64, 1911.
[2] *Proceedings of the American Philosophical Society*, 51, 1912.
[3] *Lick Observatory Bulletin*, **6**, 125, 1910.

Of a similar nature is the relation of the number of spectroscopic binaries, and their period, to spectral class.[1] The percentage of binaries thus far known among stars of Class B is far higher than for any other class, and decreases steadily as we advance toward M. This preponderance of "early class" binaries may, however, be due to their greater range and shorter periods. Time will show whether there be not as many among stars of the "later" classes. Hence this percentage is not of so much value in the problem as is the sequence shown in the periods and eccentricities between B and M. At the same time, the period and eccentricity of orbit increase with type. Periods of a day or less are confined to Classes B and A; those of 27 years and over to F and succeeding classes; in Class B but one period longer than 75 days has been found; in Classes G to M nothing shorter than 100 days.

Finally, we have the evidence, already referred to, of the association of the nebulous regions with stars of Classes O, A, and B, but never with those of Classes G, K, M, and N. When we see such "early class" stars either surrounded by nebulosity, as are the *Pleiades*, or close neighbors of an extended nebulous region, we must feel that the circumstantial evidence, at least, is strong that here we have stars in the making.

So much for the data upon which to base a theory of evolution. We now return to the question of the proper sequence of the stellar spectra. Two opinions are held, as has been said, as to the order. In the one, the order of evolution is that of a constantly cooling body,—stars of highest temperature and greatest intrinsic brightness being the earliest representatives, stars of relatively low temperatures the latest. This order coincides with that of the Harvard classification and is substantiated by the evidence offered by each of the investigations outlined. On the other hand, we have the order represented by LOCKYER's classification, in which the classes are arranged along a curve of temperature which begins with stars of relatively low temperature, ascends to a maximum in the hydrogen stars, and descends once more to low temperatures. The stars on the ascending branch of the curve differ from those on the descending branch (LOCKYER),[1] (1) in the greater continuous absorption in the violet and ultra-violet, especially at low temperatures; (2) in the relative thinness of the hydrogen lines at high temperatures; (3) in the greater thickness and intensity of the metal lines throughout; (4) in the relatively greater thickness of the lines of helium at the temperatures at which they appear. The case for this arrangement has been put by RUSSELL:[2]

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[1] *Lick Observatory Bulletin*, 6, 17, 1910.

"Assuming a star grows denser as it advances in evolution, that it is in equilibrium under its own gravitation and without sensible external disturbance, that the material in it behaves like the gases with which we are familiar,—it has been shown by RITTER and others that such a star will grow hotter as it contracts until its density reaches a critical value probably between those of air and water, and nearer the latter. The temperature then reaches a maximum, and later decreases. Stars whose surface temperature has a value less than maximum will be of two kinds: one early in evolution, of rising temperature, large diameter, and low density; the other, late in evolution, of falling temperature, small diameter and high density. The former will give out many times more light. As contraction proceeds, stars having angular motion will break up into pairs, those formed first having the longest periods. The farther evolution proceeds, the greater will be the proportion of such pairs among the whole number of stars. Periods less than a day or two cannot arise unless the density is near or beyond the critical density. The proportion of these is greatest for Type B, and least for K and M. Short periods are confined to Types B and A; systems of great mass are almost all of Type B. The relation between period and eclipse-duration in binaries of the *Algol* type (Types B and A) show that their densities are close to the critical density. The distributions of proper motions among stars of a given apparent brightness and spectral type shows (HERZSPRUNG) that the redder stars from G on, fall into two groups—one remote, of small proper motion and great luminosity; the other near us, of large proper motion and small luminosity. The stars of the first kind, being visible at great distances, form a disproportionately large percentage of the naked-eye stars—from 85 per cent for Type G, to 100 per cent for Type M, for which even the nearest of the stars of the second sort are invisible to the naked eye."

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[1] *Philosophical Transactions*, **184**, (A), 675, 1892.

[2] *Science*, **32**, 833, 1910.

Many of the observed facts are explained upon this hypothesis. In the peculiar radial velocities of the stars and their relation to spectral class (on the basis either of LOCKYER's classification or that of Harvard) are facts, however, which seem at variance with it. The percentage of velocities lower than those of Class B among stars of Classes A to M on the ascending branch of the temperature curve, which is required by the sequence observed for stars of decreasing temperature, is not forthcoming. The mean velocity for Class M should be the lowest observed, since, as RUSSELL states, it is based exclusively upon stars of small proper motion and great luminosity, among the earliest if not actually the first, in point of evolution, on the LOCKYER hypothesis. The average, as we have seen, is the highest, if we except that of the planetary nebulæ.

On the whole, then, the Harvard order seems at present to be the more satisfactory. The following table gives, in brief, this order, together with such of the arguments for it as can be conveniently tabulated. The headings are self-explanatory:

Class.	Spectrum.	Average Velocity.	Binaries.
O	Bright bands. H and He present.	6.2^{km}	Very few visual binaries. One in three are spectroscopic binaries, with periods generally short and eccentricities small.
B	Absorption lines. He at maximum. H strong. Ca (K) and Mg present.		
A	Absorption lines. H at maximum. Ca (K) and Mg stronger. Enhanced lines of metals present.	10.5^{km}	Numerous visual binaries. About one in six are spectroscopic binaries; periods longer than for Classes O and B.
F	Absorption lines. H weaker. Ca (K) stronger. Enhanced lines strong. Arc lines present.	14.4^{km}	
G	Absorption lines. Ca (H and K) stronger. Enhanced lines weaker. Arc lines strong.	15.0^{km}	Numerous visual binaries. About one in six are spectroscopic binaries; periods generally long.
K	Absorption lines. Ca (H an K) very strong. Enhanced lines very weak.	16.8^{km}	
M	Absorption lines. Absorption of short wave-lengths strong. Bands present, due to chemical compounds.	17.1^{km}	Very few binaries, either visual or spectroscopic.
N	Absorption lines. Absorption of short wave-lengths strong. Bands present, due to carbon.	.....	Unknown.

Some questions remain, for which we have as yet no answer to suggest: the position of the bright-line helium stars and the Wolf-Rayet stars in the line of evolution, the relation between planetary nebulæ and the novæ, whose spectra have points of similarity. More fundamental perhaps is the question of the meaning of the hazy lines in some spectra of Classes A and F, the differences, not of the intensity of the lines but in their definition, which exist among the spectra of these classes, and which were recognized in one of the earliest Harvard classifications. In the light of the advance already made, however, and of the increase in the number and power of our instruments, we may be confident as to the final solution of this problem of the evolution of the stars.

May, 1913.

THE NUMBER OF STARS IN THE UNIVERSE.

By R. H. Tucker.

Many attempts have been made to form an estimate of the number of stars visible in our most powerful telescopes, or to be distinguished with the aid of photography; and speculation has been rife as to whether the universe may extend beyond the limits at which stars have been actually found to exist. It has been impossible to make counts of more than very limited areas, from which, by comparison and approximation, the estimates may be extended to larger areas, and to the whole sky.

Herschel's early set of "gauges" were counts of stars, made in various parts of the sky, with the object of forming a comparative estimate of the "richness" in many directions; thus illustrating, possibly, the form and extent of the universe of visible stars. One of his recorded estimates is five and a half million stars to the fourteenth magnitude, in the sky. But Struve, at about the same epoch, estimated twenty million of the same grade.

The most common estimate has been that fifty million would be visible in our best modern telescopes. In a recent number of *Harper's Magazine*, WILLIAMS has given the number as one hundred million, with the aid of photography. It is well known that the photographic plate, with long exposure, will record stars much fainter than are visible with the same telescope. Photography has probably given impressions of stars that would be ranked as twentieth magnitude, on the adopted scale. The greater part of the recently discovered asteroids, from twelfth to sixteenth magnitude, have been found by photographing the sky with comparatively small telescopes. And the latest known additions to the planetary system, the faint satellites of *Jupiter* and *Saturn*, were discovered by photography, and are generally not to be detected with direct vision in the most powerful telescopes existing.

To illustrate the limits of vision of our telescopes, we may start with the sixth magnitude as visible to the naked eye under usual conditions, though a well-trained observer can detect stars one grade fainter, under the best conditions. With a telescope of one inch objective, the ninth magnitude may be seen; a 10-inch objective should show the fourteenth, a 16-inch should show the fifteenth, and our most powerful refractors, with nearly 40-inch objectives, are required to make visible the stars of seventeenth magnitude. The recently equipped five-foot reflector at Mount Wilson should reach nearly to the eighteenth magnitude, and the projected 100-inch reflector, for the same observatory, should extend the visible limit close to the nineteenth magnitude.

The limits of the several parts of the *Durchmusterung* have been noted in previous papers in these *Publications*.[1] For ARGELANDER, ninth magnitude complete, with stars certainly of tenth, but apparently going down to eleventh magnitude on the photometric scale, the faintest that could have been seen with his telescope. SCHÖNFELD and Córdoba could have reached the twelfth magnitude, and the photometric estimates rank some of the stars catalogued as of that grade; the former was planned to be complete to nine and a half, the latter to tenth magnitude. The measured images of the *Cape Photographic Durchmusterung* give limits for different regions, ranging from 9.6 to 11 magnitude, and it is probably complete, nearly, to the ninth magnitude. Its scale, founded upon comparison with the magnitudes of GOULD's zones, does not differ widely from the visual *Durchmusterung* scale.

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[1] *Publications A. S. P.*, No. 147 and No. 148.

This entire project for taking a census of the sky, as it might be described, finally includes in round numbers 315,000 stars for the northern portion, an average of fifteen to the square degree, and about 775,000 stars in the southern sky, an average of thirty-seven to the square degree. The proportion of those enumerated at Córdoba, rising in parts to above sixty to the square degree, if continued throughout the sky, would give two and a half million stars. These averages of distribution include the "Milky Way," in which the density of stars of the fainter grades is twice as great as the average density of the whole sky.

It is often asked, How many stars are known, so as to be recognized by astronomers. Many of the old observers were so familiar with the constellations that all the easily visible naked-eye stars could be located, and in a sense could be named, within their respective families. Some modern observers, comet seekers especially, have familiarized themselves with the constellations in this way, for the part of the sky visible above the horizon at one place. Taken singly, only a few very bright stars or distinctive colored or double stars would have been recognized. But we have this census of the stars to the ninth magnitude, and to the tenth for a part of the sky, and it could be said that the astronomer with a telescope could identify any one of these million stars—it is a common detail of his practice to make such an identification.

The *Durchmusterung* includes all of the stars, practically, that can be precisely observed for direct measures of position, with modern meridian instruments. For the positions of the fainter stars of this scheme, as well as for positions of stars too faint to have been included, recource must be had to differential measurement with larger equatorial telescopes, or to the measurement differentially of photographic plates covering the region.

On the visual *Durchmusterung* has been based the international scheme of meridian-circle observations, in the *Gesellschaft Zones*. These are now complete for the northern sky to 80°, and have been published to 18° south declination, leaving one zone to be completed to 22° south, the limit of SCHÖNFELD'S *Durchmusterung*. Some observations on the same plan, and extending below —22°, were carried on during the administration of the late Dr. J. M. THOME at Córdoba, based upon the Córdoba *Durchmusterung*. The fifteen northern zones contain the meridian-circle places of about 130,000 stars, allowing for the overlapping of the margins of the several zones, 10′ or 20′ in the individual parts. They were planned to be complete to the ninth magnitude, and to contain also as many of the fainter stars as possible that had been previously observed with the meridian circle. The visual scale of ARGELANDER gives an equivalent of about two hundred thousand stars of ninth magnitude in the whole sky, and the tenth magnitude should include about three quarters of a million. The northern Gesellschaft zones would appear to include an equivalent of the enumeration to the magnitude 9.2 of ARGELANDER'S scale, but would not be complete to any limit below 9.0 of the same scale.

The five southern zones, to —22°, allowing for the overlapping margins, and estimating the unpublished zone, should contain about forty thousand stars. They would appear to include an equivalent of the enumeration to 9.1 of ARGELANDER'S scale, which is close to that of SCHÖNFELD at this point. Including GOULD'S *Zone Catalogue*, which gives positions of 73,000 stars of less precision than those of the Gesellschaft scheme, there are accordingly above 240,000 stars, for which fairly good meridian-circle observations are available. The test of modern use of the zone observations shows them to be generally very reliable, and with actual errors not larger than had been anticipated.

For fainter stars, the proposed chart of the whole sky by the international photographic scheme is to extend to the fourteenth magnitude, well within the visual limits of the 13-inch telescopes employed in the execution. The catalogue of star positions, from shorter exposures with the same instruments, is to extend to the eleventh magnitude inclusive. This catalogue has been estimated as likely to contain two million stars for the whole sky, which would be less than the extent of the Córdoba *Durchmusterung*, were that to be carried beyond its limits in the southern sky. For the charts, LOEWY originally estimated thirty million stars to the fourteenth magnitude; but the Greenwich observers, after completing some portions of their section of the scheme, have arrived at an estimate of fourteen million to that grade.

For the estimates of the photometric scale reference may be made to the *Annals of Harvard College Observatory*. On page 178, volume 48, table XXI gives the estimate to the magnitude 13.5, and there would evidently be about nine million stars of the fourteenth magnitude of that scale. On the page following, Professor PICKERING estimates eighteen million to the fifteenth magnitude. The photometric enumeration is smaller than the visual, beginning at the faint telescopic grades. Thus, at 9.0 the summation is about two thirds that of ARGELANDER. The tenth magnitude includes about one half the number which would result from the extension of ARGELANDER'S scale to that grade. There are less than one million in the estimated eleventh magnitude, which is half the estimate of the photographic charts.

There is a very decided drop in the value of the term *b*, in the formula which has been used to represent the summation of the various grades of stars on the absolute scale of magnitudes as the fainter stars are included. Up to the *Durchmusterung* limits, the value of *b* has been found to be nearly 4. For the fainter stars, so far estimated, the value of *b* soon falls to the neighborhood of 2. The value adopted in the photometric summation drops from 3 at eighth magnitude to about 2 at thirteenth magnitude. It appears to me that this decrease in the relative numbers of the fainter stars is an indication not only of the approach to the limit of the power of our telescopes, but may be also an indication of the limit of the actual extent of the stellar universe.

In a recent number of the *Observatory*, January, 1913, there is an estimate by D'ESTERRE, based upon the count of stars on a large number of photographic plates, which he had exposed for records of variable stars, and of possible new stars. He has the count of the stars on his plates to the magnitude [illegible].2 of ARGELANDER, and the count also to 12.5, the value of *b* in this range of magnitude being 2.6. He concludes with an estimate of nearly ten million stars to the fifteenth magnitude, in the Milky Way. Assuming the distribution in that part to be twice as dense as the average for the whole sky, and that the Milky Way covers a quarter of the sky, this estimate would give twenty million stars to the fifteenth magnitude in the whole sky. For the range of magnitude from 9 to 15, the value of *b* would be 2.15.

From the count of the stars on the charts, which were made here with the 36-inch telescope, for standards of magnitude of the faintest stars visible with that instrument, the proportions of the various grades may be used to estimate the distribution in the sky. But the area covered by the charts is too small to give any considerable weight to the results.[1] The average of 700 stars to the square degree, and the relative proportion of the brighter stars in the charts, would give the following estimates for the whole sky:—

2	million	stars	to	11th	magnitude	$b = 2.59$
6	"	"	"	13th	"	2.08
13	"	"	"	15th	"	1.84
29	"	"	"	17th	"	1.65

The values of *b* here tabulated would result from the summation at ninth magnitude, compared with each successive grade. The estimate, based on this small area, gives too large a number for the stars to ninth magnitude, but at eleventh magnitude the estimate is close to that of the photographic catalogue. For the fainter grades, the estimates appear to be too small.

It is probable that the extent of visibility in our largest telescopes would be about one thousand stars to the square degree, on the average over the whole sky. This is a convenient number to recall, and possibly is as close an estimate as we are justified in making. It would give about forty million stars down to the seventeenth magnitude inclusive. Photographic plates, with large telescopes, might reveal a proportion down to twentieth magnitude that would be equivalent to one hundred million stars, which is again an easy number to fix in mind, if that can be considered as a point in its favor. We have but little basis to estimate the faintest grades, and it will be a long time before our knowledge will be much extended in this direction. Even the count of the stars in one of the great clusters has been found to be exceedingly difficult; by taking the number in small, selected, representative portions, an estimate of the total number may be made. Photographs of the clusters reveal the central part too much blurred by the condensation of the stars to permit of actual counts. We are rather confident that greater telescopic power will not add to the number of stars visible in a very much increased ratio.

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[1] *Publications A. S. P.*, Vol. VIII, page 95.

The proportion of stars to a square degree gives us useful figures in practice, for planning work of research; and the figures from various authorities make a convenient test for the relation of the respective magnitude scales. The proportion varies considerably for different parts of the sky, including some condensed regions outside the Milky Way and some notably bare regions like an area in the constellation *Scorpio*, which used to puzzle us when we first observed the *Durchmusterung* of that region. Below is a tabulation, formed from the various sections of our census and condensed from extensive counts made for this purpose.

For ARGELANDER'S *Northern Durchmusterung*, there is an exact count by tenths, made by LITTROW, and already referred to in a previous note. The article in the *Astrophysical Journal* for May, 1898, gives the basis for the figures of the first ten degrees of Córdoba, to — 32°. The scale of Córdoba below — 42° had evidently been changed, and a special count of representative portions of the zone — 50° has been made, to illustrate the character of the change. Similarly, counts have been made in the zones, — 12° of SCHÖNFELD, and — 36° of the Cape *Photographic Durchmusterung*, to give the figures of average distribution. For the Harvard Photometry, the figures have been taken from table XXI, volume 48, page 178. Exact counts of SCHÖNFELD and of the Cape are available, for the magnitude 9.0.

NUMBER OF STARS PER SQUARE DEGREE.

Mag.	Arg. N.D.N.	Schön. —12°	Cór. —32°	Cór. —50°	Cape —36°	H. Photom.
7.0	0.39	0.3	0.4	0.6	0.4	0.36
7.5	0.68	0.6	0.8	1.0	0.7	0.64
8.0	1.23	1.0	1.5	1.4	1.5	1.11
8.5	2.34	1.9	3.1	2.4	2.9	1.91
9.0	4.90	4.65	6.7	4.5	5.85	3.26
9.1	5.66	5.5	7.9	5.0	6.8	...
9.2	6.67	6.4	9.4	5.6	8.6	...
9.3	8.19	7.6	10.8	6.3	9.3	...
9.4	9.89	9.0	12.6	7.7	12.0	...
9.5	15.27	11.3	15.6	9.0	12.7	5.46
9.6	...	12.3	19.1	10.6	15.6	...
9.7	...	13.3	23.9	12.8	16.6	...
9.8	...	15.5	29.4	16.6	20.5	...
9.9	...	16.0	34.1	21.7	21.0	...
10.0	...	18.1	55.0	61.7	24.5	9.05
10.5	...	...	...	...	31.4	14.6
11.0	...	...	...	...	...	23.2
11.5	...	...	...	...	...	36
12.0	...	...	...	...	...	54
12.5	...	...	...	...	...	80
13.0	...	...	...	...	...	116
13.5	...	...	...	...	...	164
14	...	...	...	...	...	(225)
15	...	...	...	...	...	(400)
16	...	...	...	...	...	(600)
17	...	...	...	...	...	(800)

The flexible nature of ARGELANDER's 9.5 is evident in the above table. It is equivalent to the summation to 9¾ of its own scale, and undoubtedly includes many tenth-magnitude stars. This point is often overlooked in the discussion of ARGELANDER's magnitudes. Thus, in a note by J. J. PLUMMER,[1] when discussing the light of the stars, by including all those catalogued by ARGELANDER to 9.5, he independently arrives at the conclusion that this limiting grade probably extends much below that point.

SCHÖNFELD's scale appears to be consistent throughout, and his section may really include most of the tenth-magnitude stars. The first two volumes of Córdoba estimate about two tenths brighter than ARGELANDER from eight to nine and a half, and the 9.5 of Córdoba, which agrees in the table with ARGELANDER's enumeration at that point, probably corresponds to stars one quarter of a magnitude fainter, on the visual scale. The ten of Córdoba is equivalent to the summation to 10¼ of its own scale, or probably to the 10½ of the visual scale.

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[1] *Monthly Notices Royal Astronomical Society*, for June, 1877.

The change in the scale of the later volume of Córdoba is evident in the table. There is a lack in the proportion of estimates between ninth and tenth magnitudes, and a great preponderance of the limiting grade, 10, which will also be evident in the casual inspection of the pages of Volume XVIII. This grade contains nearly three times as many stars as were catalogued up to 9.9, and fourteen times as many as are included up to 9.0. The estimates appear to be about three tenths fainter than those of the two earlier volumes, between 9 and 9¼, while the actual limit extends but slightly farther.

The great increase in the number of the fainter grade had been noticed by NEWCOMB, and was commented upon in his note in the *Astronomical Journal*, No. 507, September, 1901. It is not clear, however, that NEWCOMB appreciated the fact that the 10 of Córdoba was also a flexible grade, and was intended to include many stars estimated as fainter than tenth magnitude.

The figures for Cape —36°, which is south of the point where the photographic scheme decidedly enlarged its extension, show fair agreement with the visual estimates. Below tenth magnitude the photographic catalogue contains but few stars of each grade, and the limiting grade evidently varies widely in various parts.

The difference between the photometric and the visual scale, for faint stars, is very evident in the figures of the table. The difference begins to be noticeable at the eighth magnitude. Approximate estimates have been included for the faintest grades visible, although such extension is not to be recommended, in the absence of actual counts sufficient to form a basis for it. The proportion of 800 stars of seventeenth magnitude to a square degree would give, quite precisely, thirty-three million stars in the whole sky, 41,253 square degrees.

One may explain, if it is not possible to reconcile this difference, by the circumstances of the estimates of magnitude.

The visual observer, in endeavoring to grade all the stars in classes, may take too large a difference of brightness to represent the distriction of a quarter of a magnitude, a very small quantity to be estimated, as he goes down in the scale beyond the types of stars from which he must form his magnitude scale. The photometric measures may have developed a tendency in the contrary direction; taking too small a difference of scale reading to represent the difference of a tenth, or of a quarter of a magnitude. The photometer has the great advantage that large differences of brightness can be measured, and used as checks, assuming that the instrument gives consistent and authentic values for the steps down from one type of star to another, at all parts of the scale of brightness.

A great amount of detailed comparison of the photometric and visual D. M. magnitudes has been given in the latest publication of the Harvard College Observatory, Parts 6 and 7 of Volume 72, which were received here after the figures of this note had been prepared.[1]

July 12, 1913.

THE DERIVATION OF THE RADIAL VELOCITY EQUATION.

By G. F. Paddock.

The radial velocity equation representing the component of velocity of binary stars in the direction of the Sun was first derived by Lehmann-Filhes.[2] His method, which follows in brief, was the differentiation of the co-ordinate z, whose origin is at the center of motion and whose direction is along the line of sight. Let—

$a =$ semi-major axis;

$e =$ eccentricity;

$i =$ inclination of the orbit plane with respect to the plane tangent to the celestial sphere;

$\omega =$ longitude of periastron from the receding or ascending node;

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[1] In Campbell's "Stellar Motions," recently issued from the Yale University Press, he refers to the number of stars observable in our greatest telescopes as being about one hundred million. (Page 118.)

[2] *Astronomische Nachrichten*, **136**, 17.

$u = v + \omega$ = longitude in the orbit measured from the receding node in the direction of motion;
v = true anomaly;
p = semi-parameter $= a\,(1 - e^2)$;
μ = mean daily motion;
r = relative radius vector;
t = time;
f = constant of attraction in the system;
k = Gaussian constant for the solar system;
m = mass of either component;
$M = m_1 + m_2$ = total mass;
K = semi-amplitude of velocity oscillation;
V = radial velocity in kilometers per second relative to the Sun,—

Then

$$Z = r \sin i \sin u,$$

$$\frac{dz}{dt} = \sin i \sin u \frac{dr}{dt} + r \sin i \cos u \frac{du}{dt}.$$

Taking from the theory of orbital motion in a plane the expressions

$$\frac{dr}{dt} = \frac{f}{\sqrt{p}}\, e \sin(u - \omega),$$

$$r\frac{du}{dt} = \frac{f}{\sqrt{p}}\,(1 + e \cos[u - \omega]),$$

we derive

$$\frac{dz}{dt} = \frac{f}{\sqrt{p}} \sin i\,(\cos u + e \cos \omega),$$

or

$$V = K\,(\cos u + e \cos \omega).$$

It is obvious that this equation should be derivable from the fundamental equations of motion and it may be of interest to show how it may thus be derived, although a simple process.

The fundamental equations for the z components of motion of a binary system are

$$\frac{d^2 z_1}{dt^2} = -k^2 m_2 \frac{z_1 - z_2}{r^3}.$$

$$\frac{d^2 z_2}{dt^2} = -k^2 m_1 \frac{z_2 - z_1}{r^3}.$$

Since radii vectores are inversely proportional to the masses, we have

$$r_1 + r_2 = r = \frac{m_1 + m_2}{m_2} r_1 = \frac{m_1 + m_2}{m_1} r_2,$$

$$z_1 - z_2 = z = \frac{m_1 + m_2}{m_2} z_1 = - \frac{m_1 + m_2}{m_1} z_2.$$

Hence we have

$$\frac{d^2 z_1}{d t^2} = - k^2 \frac{m^3_2}{(m_1 + m_2)^2} \frac{z_1}{r^3_1},$$

$$\frac{d^2 z_2}{d t^2} = - k^2 \frac{m^3_1}{(m_1 + m_2)^2} \frac{z_2}{r^3_2},$$

$$\frac{d^2 z}{d t^2} = - k^2 (m_1 + m_2) \frac{z}{r^3}.$$

The last equation applies to relative motion. The coefficients on the right-hand side represent the constant of attraction for each case, as follows:—

$$f_1 = k \frac{m^{\frac{3}{2}}_2}{m_1 + m_2}, \quad f_2 = k \frac{m^{\frac{3}{2}}_1}{m_1 + m_2}, \quad f = k \sqrt{m_1 + m_2}.$$

The equations are therefore of the same form and give exactly similar integrals and orbits. The integration need be performed for only one,— for example, the last,—and may be effected with the help of the integrals of relative motion in the orbit plane, namely,—

the orbit equation,

$$r = \frac{p}{1 + e \cos (u - \omega)},$$

the areal velocity,

$$r^2 \frac{d u}{d t} = k \sqrt{M} \sqrt{p},$$

the orbital radial velocity,

$$\frac{d r}{d t} = \frac{r^2 e \sin (u - \omega)}{p} \frac{d u}{d t} = \frac{k \sqrt{M}}{\sqrt{p}} e \sin (u - \omega).$$

Then since

$$z = r \sin i \sin u,$$

the last of the equations of motion becomes

$$\frac{d^2 z}{d t^2} = -\frac{k\sqrt{M}}{\sqrt{p}} \sin i \sin u \frac{d u}{d t}.$$

Integration gives

$$\frac{d z}{d t} = \frac{k\sqrt{M}}{\sqrt{p}} \sin i \cos u + c.$$

To determine the constant of integration c, let $u = \frac{1}{2}\pi$.
Then

$$c = \left.\frac{d z}{d t}\right]_{u=\frac{1}{2}\pi} = \sin i \sin u \left.\frac{d r}{d t}\right]_{u=\frac{1}{2}\pi} = \frac{k\sqrt{M}}{\sqrt{p}} \sin i \cdot e \cos u.$$

Then putting

$$V = \frac{d z}{d t} \text{ and } K = \frac{f \sin i}{\sqrt{p}},$$

we have

$$V = K\,(\cos u + e \cos \omega).$$

The V and K may now refer to either relative motion or to motion of either component with respect to the center of mass.

Since

$$\mu\, a^{\frac{3}{2}} = f,$$

we have, if k be given for the unit of time one second,

$$K = k_s \sqrt{M}\,\frac{\sin i}{\sqrt{p}} = \frac{\mu}{86400}\,\frac{a \sin i}{\sqrt{1 - e^2}}$$

$$K_1 = \frac{k_s\, m_2^{\frac{3}{2}}}{m_1 + m_2}\,\frac{\sin i}{\sqrt{p_1}} = \frac{\mu}{86400}\,\frac{a_1 \sin i}{\sqrt{1 - e^2}}$$

$$K_2 = \frac{k_s\, m_1^{\frac{3}{2}}}{m_1 + m_2}\,\frac{\sin i}{\sqrt{p_2}} = \frac{\mu}{86400}\,\frac{a_2 \sin i}{\sqrt{1 - e^2}}$$

Then since $\omega_2 = \omega_1 + \pi$,
and if V_1 and V_2 are the velocities relative to the Sun and γ the velocity of the center of mass relative to the Sun, we have for the velocity equations of each component of a binary system,

$$V_1 = \gamma + K_1\,(\cos u + e \cos \omega),$$
$$V_2 = \gamma - K_2\,(\cos u + e \cos \omega).$$

PERSONAL EQUATION IN TRANSIT OBSERVATIONS.

By R. H. Tucker.

In May, the difference of personal equation in chronographic transit observations was determined for Dr. C. C. Kiess and the writer, by observing the same groups of stars on two nights, with the meridian circle. On the first night the difference of clock corrections for the two observers was T-K = $+0^s.012$. On the second night the difference for the alternate groups was T-K = $-0^s.013$.

Thus, from this brief comparison, the difference of personal equation would appear to be negligible in the third place of decimals.

The errors of tabular right ascension are eliminated by the alternation of the groups of stars, and the errors of the determination of the instrumental corrections practically disappear also; the combined effects from both sources being represented by the mean differences above. Collimation was determined by opposing collimators, level from reading on the nadir, and azimuth from observations of circumpolar stars, on both nights by observer T.

The probable error of a clock correction determined by one star would be $\pm 0^s.028$, for either observer; while the differences of residuals would give $\pm 0^s.017$, as the probable error of a determination free from the effect of error in the tabular right ascension.

July 2, 1913.

THE UNIT OF STELLAR DISTANCE.

By Heber D. Curtis.

Elsewhere in this number of the *Publications* (in Abstracts from Astronomical Publications), Dr. Paddock gives a timely resumé of the various suggestions which have been put forward recently for a new unit of stellar distance. The suggested units are:

The andromede = distance of *Andromeda* nebula, 1,600 to 8,000 light-years.

Macron, parsec, astron, astrometer, siriometer = distance corresponding to a parallax of one second of arc = 3.26 light-years.

Sinusweite = distance corresponding to a parallax of 0".2 = 16.3 light-years.

Before any such unit is adopted, a general agreement among astronomers would be necessary, with full discussion of the needs for such a change, and this seems to be a favorable opportunity for the present writer to express his own personal disapproval of the units suggested.

The unit for the enormous distances needed in stellar studies should possess the following characteristics, or as many of them as possible:—

A. *It should depend upon concepts of space, time, and matter as fundamental, and as accurately known as present scientific knowledge permits.*

B. *It should be of such a nature as to be comprehended by the general reader, and by students with but elementary training.*

C. *It should be of such magnitude, preferably, that but rarely will statements involving the unit need to be expressed in numbers inconveniently large, or fractions inconveniently small.*

So completely does the customary and well-known unit of the light-year fill all these requirements, that any change appears to me not only to be entirely unnecessary, but even to savor a little of pedantry. To consider, in detail, the requirements outlined above:—

A. The velocity of light, from our present knowledge, appears to be as fundamental a constant in the world of matter as is e or π in mathematics; it is far more than merely the value of the velocity of light, as it expresses the relations between the electrostatic and electromagnetic units, and enters into many equations in pure physics. It is probable that we know its absolute value to-day at least within one ten-thousandth. As to the fundamental nature of our year and our day as a unit of time nothing need be said. The length of the *astron* depends upon the solar parallax; it is by no means certain that we know this latter constant with an error less than one thousandth. As to the *andromede*, will any one claim that we know the distance of the *Andromeda Nebula* within fifty per cent of its true value? Or the true distance of *Sirius* within five per cent? (SEELIGER'S *siriusweite* is the distance corresponding to a parallax of 0″.2; the modern values of the parallax of *Sirius* range from 0.″34 to 0″.40.) The length of certain waves of light has been adopted as the standard of length for the determination of the meter, and the velocity of light would appear to be an equally fundamental and fitting starting-point for our greatest standard of length.

B. The parallax of the fixed stars, as defined and used by astronomers, has no meaning whatever to the average layman, and the definition of an *astron* as such a distance that the mean radius of the Earth's orbit would subtend an angle of one second of arc, would be equally meaningless and carry with it no conception of the order of magnitude involved; the layman has forgotten, if he ever knew, just how small a quantity a second of arc is. He knows, however, that the speed of light is enormous, if he does not recall the exact figures, and the concept of the distance traveled by light in one year is easily grasped by him; his conception of the order of magnitude of a light-year is roughly correct, even though he may not know that this distance is nearly six trillion miles. The astronomer's convenience need not be considered; he will doubtless continue, as in the past, to use parallaxes expressed in seconds of arc in his studies and computations involving stellar distances. I can see no advantage from his standpoint in referring to the distance of a star as 14.3 *parsecs*, instead of saying that the star has a parallax of 0.07 seconds of arc; still less can I conceive that he would find it more convenient to say that the distance is 0.029 *andromede*, or 2.8 *siriusweiten*, rather than 46 light-years.

The light-year is a unit of convenient size when compared with the dimensions of the known stellar universe. Known stellar distances range from about four light-years to five hundred light-years, with uncertainties in the higher values, for the distances of *individual* stars, of from fifty to one hundred per cent. Beyond five hundred light-years we enter the domain of speculations, which, while of great interest and value, are still but speculations, founded upon more or less probable assumptions as to the absorption of light in space, conditions of surface luminosity, etc. Whether the Milky Way is three thousand, or several million light-years across, the light-year is still a usable unit. Should the advance of our knowledge ever bring it to pass that a larger unit is needed, the logical step would appear to be a decimal multiple of the light-year, the light-century, or the light-millenium.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1913.

By MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	Sept. 7,	5^h	6^m	A.M.	First Quarter	Oct. 6,	5^h	46^m	P.M.
Full Moon	" 15,	4	46	A.M.	Full Moon	" 14,	10	7	P.M.
Last Quarter	" 23,	4	30	A.M.	Last Quarter	" 22,	2	53	P.M.
New Moon	" 29,	8	57	P.M.	New Moon	" 29,	6	29	A.M.

The fourth eclipse of the year, a total eclipse of the Moon, occurs on the night of September 14th-15th, the beginning visible generally in North American except the extreme northern portions, the Pacific Ocean, Australia, and eastern Asia; the ending visible generally in Alaska, the Pacific Ocean, except the eastern portions, Australia, and Asia.

CIRCUMSTANCES OF THE ECLIPSE, PACIFIC TIME.

Moon enters penumbra	September	15,	$1^h\ 40^m$	A.M.
Moon enters shadow	"	15,	2 52	A.M.
Total eclipse begins	"	15,	4 1	A.M.
Middle of the eclipse	"	15,	4 48	A.M.
Total eclipse ends	"	15,	5 35	A.M.
Moon leaves shadow	"	15,	6 44	A.M.
Moon leaves penumbra	"	15,	7 56	A.M.

The fifth and last eclipse of the year, a partial eclipse of the Sun, will occur on September 29th. The region of visibility is confined to the southern hemisphere, and includes Madagascar and a part of South Africa. The maximum obscuration of the Sun is about 82 per cent of its diameter.

The autumnal equinox, when the Sun crosses the equator from north to south, occurs September 23d, about 8 A. M. Pacific time.

Mercury on September 1st is a morning star, rising a little more than an hour before sunrise, and may be seen in the early morning twilight under good weather conditions; but this condition lasts only a day or two, as the planet is rapidly approaching the Sun, and reaches superior conjunction, becoming an evening star on the morning of September 16th. It remains an evening star through the rest of the month and throughout October, reaching greatest east elongation on November 1st; but as the motion of the planet carries it to a position nearly 10° south of the Sun there is practically no possibility for naked-eye observations during October, the interval between the setting of the Sun and of the planet being less than one hour.

Venus remains a morning star, rising a little more than three hours before sunrise on September 1st, this interval diminishing to a little more than two hours by the end of October. During this period the planet moves 71° eastward and 21° southward from the western part of *Cancer*, not far from α and β *Geminorum*, through that constellation and *Leo* into *Virgo*. On the morning of October 25th there wil be a very close conjunction with the first-magnitude star *Regulus*, α *Leonis*, at the time of nearest approach the planet being about half the Moon's apparent diameter north of the star. As

Venus on October 1st is about four times as far from the Earth as it was during its time of greatest brilliancy during the spring, it will not be nearly as conspicuous as it was at that time, although still much brighter than a first-magnitude star like *Regulus*.

Mars rises on September 1st about half after eleven and on October 31st at about half after nine. During the two months it moves about 31° nearly due eastward from the eastern part of *Taurus* into the eastern part of *Gemini*, and at the end of October is a little south of *Castor* and *Pollux*, the principal stars of the constellation. As the planet approaches opposition its distance from the Earth diminishes rapidly, averaging more than half a million miles daily, and on October 17th its distance from us is the same as the Earth's mean distance from the Sun. At the time of nearest approach at the end of this year the distance of the planet from the Earth will be about 60 per cent of this. During the two months the planet nearly doubles its brightness, and just before the end of October will be about one half as bright as it will be at opposition.

Jupiter is a fine evening object in the southwestern sky. On September 1st it sets shortly after midnight, and on October 31st a little before 9 P. M. At the beginning of September it is moving slowly westward, but becomes stationary and then begins to move eastward on September 4th, the entire eastward motion up to the end of October being about 5° It will then occupy almost exactly the same position it held among the stars early in July, in *Sagittarius*, a little north of the eastern end of the "milk dipper."

Saturn rises shortly after eleven in the evening on September 1st, and shortly after seven on October 31st. It is in the constellation *Taurus* east and north of the principal star *Aldebaran*, and up to September 30th moves about 3° eastward. It then begins westward, or retrograde, motion and moves about 1° in that direction during October. On October 1st it is 10° east and 5° north of *Aldebaran* and approaches the star during the month. This approach will continue until about the end of January, 1914, when the distance will be diminished to about one half that of October 1st.

Uranus is above the horizon until half after two in the morning on September 1st and until about half after ten in the evening on October 31st. It is in the constellation *Capricorn* and moves slowly westward less than 1° up to October 13th. It then begins to move eastward, but the motion is small. It remains near the fifth magnitude star *υ Capricorni*, but it is not at all easy to identify. The planet on October 1st is about 3° west and 1° 30′ south of the star.

Neptune rises at a little after 2 A. M. on September 1st and shortly after 10 P. M. on October 31st. It is in the extreme eastern part of the constellation *Gemini.*

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these Publications, and the Publication Committee has acted favorably upon the suggestions.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

Measures of Proper-Motion Stars Made with the 40-Inch Refractor of the Yerkes Observatory in the Years 1907 to 1912 by S. W. Burnham.[1]

Professor Burnham's enthusiasm in the study of relative stellar motions is untiring. For many years he has been known as the foremost living double-star observer and the one who has done more than any other since Struve's time to further this branch of astronomy. And now, at an age when most observers retire from actual work, he gives us a most important contribution to the study of the proper motions of stars, including no less than 9,500 measures made with the micrometer of the great 40-inch refractor.

The working program was made up principally of stars selected from the *General Catalogue of Double Stars*, "for reasons which will generally be apparent from the notes and observations cited in that work. By far the greater number of stars given in the *General Catalogue* as having proper motions are not included here, because the observations there cited are of recent date and further measures are not needed at this time." The measures of this list from Part II of the present volume, which may therefore be regarded, as the author says, as in a sense supplementary to the *General Catalogue*. Part I contains measures of "all other stars for which prior observations with the micrometer have been made." This is a much shorter list than the other.

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[1] Washington, D. C., 1913. Published by the Carnegie Institution of Washington. 4°, paper, pp. iv + 311.

The object of the measures is, as appears from the title, to accumulate data for more accurate determinations of proper motions of the stars. It is clear to any one who has studied the matter that such motions can be determined far more accurately from micrometer measures than from meridian observations, provided (1) that the comparison stars have no sensible proper motions, and, (2) that the time interval covered by the series of measures is of the same order as that covered by the meridian measures. The second condition can be met in due time, and BURNHAM's work, as well as that of others, has shown that the first is realized if the comparison stars are independent and faint. To quote from the brief introduction:

"For many years I have been hunting for a faint star with some certain proper motion, but so far without success; and the observations of others to this time give only negative results. It goes without saying that every star in the heavens, down to the limit of the largest aperture, must have some proper motion as well as parallax; and it is equally obvious that the one is as negligible as the other in all observations of relative positions with any astronomical instrument now in use."

This remark, of course, does not apply to the faint companions of brighter stars which share in the motion of the latter. Ultimately, we shall be able to detect the minute proper motions of the fainter stars in general by the continuation of just such measures as those in this volume, and by the comparison of photographs taken at suitable intervals.

The measures are arranged in the convenient form which we have come to expect in BURNHAM's volumes, and mechanically, the book leaves nothing to be desired. R. G. AITKEN.

July, 1913.

THE ASTRONOMICAL UNIT OF DISTANCE.

Distances in the solar system are usually expressed in terms of the mean distances of the Earth from the Sun. This mean distance is called the astronomical unit. Stellar distances, however, are so immense that this unit is of little use. The unit called the light-year is then employed to indicate, with however much or little comprehension it may induce, the distance which light travels in one year through stellar space.

In discussing distances of nebulæ, Professor VERY, of Westwood, Massachusetts, proposes as a unit the distance of the *Andromeda* nebula and the name *andromede*.[1] This unit would be of the order of one thousand light-years.

In discussions of the distribution of stars in space, of star streams and of stellar motions, there has recently come into use as a unit of distance that corresponding to a parallax of one second of arc. This distance is about three light-years. Dr. DYSON, Astronomer Royal of England, says,[2] "there is need for a name for this unit of distance. CHARLIER, of Lund, has suggested *siriometer*. Professor TURNER, of Oxford, suggests *macron* or *parsec*, which may taken as an abreviated form of the expression *a distance corresponding to a parallax of one second*. If, however, violence to the Greek language can be overlooked, the word *astron* might be adopted." Again, SEELIGER has called the distance corresponding to 0".2 of arc of parallax *siriusweite*.

Of all these suggestions the designation *astron*, or perhaps *astrometer*, would seem very appropriate.

G. F. PADDOCK.

THE RELATION OF STELLAR VELOCITIES AND MASSES.

In a recent number of the *Astronomische Nachrichten*[3] we find a discussion by H. SEELIGER upon the dependence of the velocities of the stars upon their masses. The idea of "cosmic dust cloud" has many times been applied to the stellar system. Furthermore, the conditions in this system of discrete masses have been taken to resemble those in a gas. But caution must be used in applying the laws of the kinetic theory of gas. There are certain facts which point to a far-reaching analogy between a mass of gas and the star system. First, there are numerous cases of large velocity which cannot be explained as a consequence of the gravitation of the stellar system as a whole. NEWCOMB suggested that these rapid stars may have entered from outside the stellar system. But this is not very likely nor necessary. KELVIN suggested that these large velocities might be due to near approach of bodies to others of strong attraction. A second fact which is shown by Dr. CAMPBELL'S discussion of the radial velocities of the stars is that mean radial velocities of the several spectral classes of stars increases from B to M. It is probable that early-type stars are the more massive. From all these points it may be construed that mass and velocity are inversely related. In the kinetic theory of gases the velocities of the molecules are inversely as the square roots of their masses. If this law be applicable to the stellar system the observed facts may be accounted for to a certain extent, but not satisfactorily.

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[1] *Popular Science Monthly*, 82, 294.
[2] *Monthly Notices*, 73, 342.
[3] *Astronomische Nachrichten, Band*, 194, 274.

SEELIGER has made other assumptions which have no connection with the kinetic theory of gases and by an extensive mathematical discussion obtains the result that the smaller masses must have the larger velocities. It is assumed that the masses originated by the collection of small unit masses, which possessed any values of velocity whatever. The treatment is then based upon the probabilities of the velocities and the conclusion drawn that the velocities are less as the masses are greater. The result explains observed phenomena only in a qualitative way. The full explanation of stellar velocities is yet to be found. G. F. PADDOCK.

ON THE OCCURRENCE OF THE ENHANCED LINES OF TITANIUM IN ELECTRIC-FURNACE SPECTRUM, BY A. S. KING.[1]

In the course of an investigation of the variations of the spectrum of titanium given by different temperatures of the electric furnace, special effort was made to obtain the enhanced lines and fix their place, if possible, on a temperature scale. Upon pushing the temperature of the furnace beyond 2600° C by the use of tubes with thinner walls, these walls burned through, with the formation of an arc, furnishing in the process conditions under which the enhanced lines appeared with a relative intensity usually seen in the condenser spark, although the potential at no time appeared to rise above 33 volts. The results of these experiments are summarized as follows:—

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[1] *Astrophysical Journal*, **37**, 119, 1913, (March).

1. The enhanced lines of titanium appear in the regular furnace spectrum for temperatures probably somewhat higher than 2600° C, but are very faint compared to the arc lines.

2. At still higher temperatures, while furnace conditions still exist, there are indications of a slight increase in the relative strength of the enhanced lines.

3. When the furnace tube burns through with the formation of a low-voltage arc, the consumption of electrical energy at the point being very large, the enhanced lines of titanium and the spark line λ 4267 of carbon appear with an intensity usually attainable only in powerful sparks.

4. By photographing with the slit across the image of the tube's interior, the relative strength of the enhanced lines is seen to be much greater in the center of the tube than near the wall, this effect being very pronounced in the case of the carbon spark line.

5. The vapor in the center of the broken tube shows a tendency to give a line farther to the red than that near the wall, this being shown in the increasing dissymetry of the lines from the end toward the middle. The effect is in harmony with the action of the condensed spark. E. PHŒBE WATERMAN.

May, 1913.

ASTRONOMY, BY GEORGE F. CHAMBERS.[1]

The author's motive in writing this book may be gathered from the following statements quoted from his preface: "This volume is not a formal treatise on astronomy, nor is it a mere educational text-book. . . . There is nothing profound or inconveniently deep in it, but it just gives a popular outline of leading facts. . . . My idea has been to direct the reader's attention to what may be called every-day topics. . . ."

The author has had a wide experience, both as a writer and as a lecturer, on astronomical subjects and has naturally produced a readable book, which gains a further interest from the unusually large number of illustrations. These are of varying degrees of excellence and some are very good indeed. But the eight colored plates will convey, for the most part, a wrong impression of the colors of the objects as actually seen through the telescope. The colors are made far too brilliant and too definite in their contrast to represent the reality. This applies particularly to the plates of colored double stars, and in only less degree to those of the planets.

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[1] D. Van Nostrand Co., New York, 1913. $1.50.

There are many statements in the book to which exception might be taken if it claimed to be in any sense a treatise on the subject, and only the briefest references are made in it to some of the most significant advances in the science during the past two decades. Occasionally this incompleteness may give an incorrect idea of the actual state of present knowledge, but there are few passages that are in themselves misleading.

It is particularly pleasant to find the book well printed on good paper and quite free from obvious typographical errors. Among the few that were noticed is the statement in the preface locating the Yerkes Observatory at Williams*town* instead of at Williams Bay.

R. G. AITKEN.

June, 1913.

LEHRBUCH DER SPHÄRISCHEN ASTRONOMIE, VON DR. L. DE BALL.[1]

This addition to the list of compendia of spherical astronomy is a finely printed quarto in the best style of the German bookmaker's art, and is intended to serve as a manual for the student as well as a handbook for the working astronomer. The astronomer will find in it a valuable reference book, wherein are brought together and given with very full and thorough treatment the majority of the subjects properly falling under the head of spherical astronomy, some of which have hitherto not been easily accessible.

Certain fields are treated with a fullness and rigor which seems almost superfluous as far as the needs of the working astronomer are concerned; 64 of the 387 pages are devoted to a discussion of the rotation of the Earth; with so much space available for the treatment of this phase of the subject, it would have seemed advisable to include something on latitude variation, and to have given more space to the HORREBOW-TALCOTT method. So, also, the treatment of refraction from its theoretical standpoint seems unduly full for a reference book of this sort, as 55 pages are devoted to the subject, while nothing at all is given in the important field of the spherical astronomy of the photographic plate.

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[1] Wilhelm Engelmann, Leipzig, 1912. 4 to, pp. xv + 387. $5.00.

Aside from these omissions, it will be found an unusually full and comprehensive reference book on the subject, with numerous improvements and simplifications in stating well-known methods, and not a little matter not easily accessible, as, for instance, the methods of determining the parallax of star-streams, and the chapter on astrographic determinations of position, with special reference to selenographic co-ordinates. A full and clear treatment is given of occultations, and of solar and lunar eclipses, while at the beginning of the book are collected the usual formulæ for interpolation, mechanical quadrature, least square, and spherical trigonometry. H. D. C.

GENERAL NOTES.

It is with great regret that we record the death of Professor Luis G. Leon on April 23d, at the age of forty-seven. Professor Leon was secretary of the Astronomical Society of Mexico, and the editor of the *Bulletin* of the society. Through his intense enthusiasm and zeal he did a great deal to stimulate popular interest in astronomy in Mexico, and his death is a severe loss to the Mexican Astronomical Society, of which he was the founder.

Observatories and Cities.—Modern astronomical research work, which necessitates the long exposure of photographic plates and the observation of faint stars, is gradually separating old observatories from their historic surroundings and creating new buildings in more favorable situations. The Hamburg Observatory is now settled in its new site in Bergedorf, and the new ground is bristling with domes of the latest construction. Berlin Observatory is now on the move, taking up its new position in Neu Babelsberg, not very far from its astrophysical *confrère* at Potsdam. At the present time the question is being considered as to the removal or part removal of the Paris Observatory, as the conditions on the site now occupied are not conducive to the best observational work.—(From *Nature,* June 19, 1913.)

Dr. S. A. Mitchell, Associate Professor of Astronomy at Columbia University, has been appointed Director of the Leander McCormick Observatory at the University of Virginia, as successor to Professor Ormond Stone, who retired two years ago on the Carnegie Foundation. Three who took their doctorates under Professor Stone are now on the Lick Observatory staff, and their best wishes go with Professor Stone in his well-earned retirement from active duties, and to Dr. Mitchell in his new field of work. During the past year Dr. Mitchell has been on sabbatical leave from Columbia, and has spent his time at Yerkes Observatory in spectrographic and parallax work.

Earthquakes Versus Suffragettes.—The earthquake of July 1, 1911, did practically no damage anywhere in California, except to the old brick dormitory at Mount Hamilton, and this was a building whose structural faults rendered it rather susceptible to shock. To replace the residence space in this building a fine dormitory building of reinforced concrete and two modern cottages have been built. These are now completed and the rather congested living conditions of the past two years, which have been necessary on the part of several members of the staff, are at an end. Some of our English colleagues evidently have to take precautions against upheavals of a different nature: witness the following note from *The Observatory*:—

"The Royal Observatory on Blackford Hill (Edinburgh) was entered on the night of May 20th-21st, and a bomb fired inside the building, immediately under the 24-inch reflector. The perpetrators obtained entry by smashing some panes of glass, and laid a fuse up a spiral staircase to a lumber-room just below the instrument. The explosion took place about 1 A. M. Fortunately, no serious damage was done to the instruments, the damage being mainly structural. A woman's handbag and some papers, which were left behind, leave no doubt as to the organization to which the crime must be attributed."

A similar attempt, with rather serious results, has been made at the Gatty Marine Laboratory of St. Andrews. This laboratory has always been open to scientific workers of both sexes, but this fact did not give it immunity. Explosives and combustibles were placed in one of the work rooms on the night of June 21st. Fortunately the fire was seen by fishermen, who gave the alarm, but the large work room was wrecked and the roof ruined before the firemen obtained control of the fire.

California has now been a suffrage State for over a year, and all critics admit that it is a success. But it is to be feared that the amendment permitting woman suffrage would have failed to pass, as it has since done in Michigan, had the militants started their "campaign" a few months earlier.

It is stated in the *Times* that Mr. CAWTHORN, of Nelson, has offered to give £10,000 to £12,000, the sum required to establish a solar physics observatory in New Zealand. This, we understand, is the outcome of a visit to New Zealand by Miss PROCTOR.

Miss SOPHIA LEVY, graduate student of the Berkeley Astronomical Department, is spending the summer at Lick Observatory as a voluntary assistant.

Mr. CARL A. BERGMANN has been appointed an assistant on the staff of the Lick Observatory, with principal duties in photography.

Director CAMPBELL left on July 17th to attend the Solar Conference which meets at Bonn, July 30th to August 6th, and the meeting of the Astronomische Gesellschaft at Hamburg, August 6th to 9th. He will sail for home on August 12th, arriving at Mount Hamilton on August 24th.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC IN HEARST HALL, BERKELEY, ON JULY 11, 1913, AT 8:00 P. M.

The meeting was called to order by President A. G. McADIE. There being no routine business before the society, he proceeded to introduce the speaker of the evening, Dr. ROBERT G. AITKEN, of Lick Observatory, who delivered an illustrated address on the subject "Among the Stars." In view of the fact that this meeting was held in conjunction with the summer sessions of the University and that it was designed to be commemorative of the twenty-fifth anniversary of the opening of Lick Observatory, it drew out an interested and appreciative audience of about five hundred people. Dr. AITKEN reviewed briefly the work [illegible] has accomplished at Lick and spoke modestly but with evident pride of its contributions to the great science to which it is dedicated. In the very nature of things his excursion "Among the Stars" was curtailed by the time limits of a single lecture, but he has a happy way of clothing skeletons with beauty and interest, and that is what he did on this occasion.

A vote of thanks and appreciation was unanimously extended to Dr. AITKEN at the close of his address.

Adjourned

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN HEARST HALL, BERKELEY, ON JULY 11, 1913, AT 7:30 P.M.

There were present President McADIE and Directors AITKEN, CRAWFORD, CORNISH, and RICHARDSON.

President McADIE announced his early retirement from California to accept a position at Harvard and asked the will of the Board as to the unexpired portion of his term. It was unanimously voted, with many compliments and regrets over his departure, that he should serve out his term, notwithstanding his absence from the State.

The following votes of thanks were extended:—

To EDWARD M. BREWER, of Boston, Massachusetts, for back numbers of the *Publications;*

To Professor SLIPHER, of Lowell Observatory, for the present of two very beautiful lantern slides of nebulæ spectrum in *Andromeda* and the *Pleiades;*

To D. S. RICHARDSON for the present to the library of one set of the Encyclopædia Britannica.

Adjourned D. S. RICHARDSON,
Secretary.

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Mr. R. G. AITKEN	*First Vice-President*
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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. AITKEN, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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STAR POSITIONS AND GALACTIC CO-ORDINATES.[1]

By R. T. A. Innes.

"The galactic circle, the great circle to which the course of the *Via Lactea* most nearly conforms. Every subject has its technical or conventional terms, by whose use circumlocution is avoided and ideas rendered definite. This circle is to sidereal what the invariable ecliptic is to planetary astronomy—a plane of ultimate reference, the ground-plane of the sidereal system."—Sir J. Herschel, *Outlines of Astronomy*, 1849, page 53.

In nearly every case concerning the motions of the heavenly bodies, the astronomer has to refer their places to the center of the Sun; so that if an observer could be heliocentric much labor of reduction would be saved. Let us try to imagine how a heliocentric observer, with all our notions upon astronomy, would start to work. His first object would be to form a catalogue of the stars, and to do so he would have to decide on the planes of reference to which their places should be referred. If a terrestrial friend should suggest that the plane of the Earth's equator should be the fundamental plane and that the direction of the intersection of the Earth's orbit with its equator should be the initial plane, I think our heliocentric astronomer would be surprised. He might say: "But both the Earth's orbit and its equator are changing constantly, and the stars are virtually fixed; would I not by choosing such co-ordinates involve myself in endless calculations? Why should I not choose some plane and starting-point nearly invariable and related in some way to the stars?" The terrestrial astronomer could only reply that his predecessors had used the Earth's equator, etc., and that the theory of meridian instruments which they used was based on the fact that the Earth rotates. But what, the heliocentric astronomer might ask, has the Earth's rotation to do with the places of the stars? Would not the stars still be in their places if the Earth ceased to rotate? Why not fix the places of your stars by photography? It gives results more precise than any meridian instrument, and from these precise places, you may, if you wish, find out the positions of the Earth's equator and orbit, but do not mix your ideas and put the cart before the horse.

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[1] Read before the South African Association for the Advancement of Science, Delagoa Bay, July 1913.

How is it that sidereal astronomy has got so involved? I think the difficulty grew in this way. Precise astronomy commenced about 1750. It is interesting to note that the oldest catalogue that the astronomer keeps on his working shelf is for the epoch 1750 and was compiled from LACAILLE's observations made in Strand Street, Capetown, with a ½-inch telescope. The other star catalogues between 1750 and 1800 are due to the labors of BRADLEY, MAYER and LALANDE. But the work of these four astronomers is remarkable in this, that although they made the observations, they did not reduce them. The prison-house of variable right ascensions and declinations was not yet ready. But early in the nineteenth century, BESSEL got all into ship-shape order. BESSEL's aptitude for all the problems of spherical astronomy was marvelous; so that to a subject which seemed unwieldly in its clumsiness, he managed to fit formulas of, when the complexity of the subject is considered remarkable neatness. The relief was so great that astronomers accepted the fetters gleefully. BESSEL's star-reduction numbers, which are published in every astronormal ephemeris, provide for the aberration of light, nutation in latitude and longitude, and the precession of the equinoxes. Thus encouraged, astronomers soon reduced the observations of LACAILLE, BRADLEY, MAYER and LALANDE to mean epochs. So long as the stars concerned are not very near the poles of the rotating sky, and the period does not exceed one century, the precession formulæ are not too unwieldy. One has to calculate for both right ascension and declination the first term of the precession which will be multiplied by t, the time elapsed, then the secular variation which is to be multiplied by $t^2/200$, then the third term of the precession, which will be multiplied by t^3. It is true that for many thousand of stars these precessional terms are already calculated, and all that remains is for the user of a catalogue to do the multiplication by t, $t^2/200$, and t^3. But the labor of making all these calculations is prodigious and it is all done to impress an imaginary motion upon the fixed stars. This motion makes it difficult to compare the places of stars in different catalogues. Thus we have in catalogues the following positions of *ε Orionis*:—

Catalogue	Epoch.	R. A.	Dec.
Lalande	1800	$5^h\ 26^m\ 3^s.66$	— 1° 20′ 27″.2
British Association	1850	5 28 36 .22	— 1 18 6 .5
Cape	1900	5 31 8 .36	— 1 15 56 .5,

indicating change in one century of

R. A. + $5^m\ 4^s.70$ Dec. + 4′ 30″.7,

whereas the real movement of the star in that time has only been 11″.66 in all: the rest is fictitious.

The use of the moving or equatorial co-ordinates of right ascension and declination is inevitable for some purposes, such as in determining the places of the Sun, the interior planets, *Mercury* and *Venus*, and the clock-stars; for finding with an equatorial telescope, rough equatorial co-ordinates such as can be read off a good star map by inspection are all that are required Why should we, therefore, impose moving co-ordinates on millions of fixed stars because we require moving co-ordinates for the Sun and a few planets and clock-stars?

I think that the reason astronomers have kept to moving co-ordinates was a belief that the use of galactic co-ordinates, to coin a term suggested not only by the nature of the problem, but by Sir JOHN HERSCHEL, would lead to formulas of even greater complexity than those given by BESSEL. When I proposed the use of galactic co-ordinates, a well-known astronomer wrote me that the idea was attractive, but that no one would look further unless numerical examples showing how it worked in practice were forthcoming. I must confess that when I took up this challenge I was not too confident that the formulas would work. In the result, I was agreeably surprised; the resulting expressions, even in the most disadvantageous cases, are hardly longer than the old methods, and in all others they are shorter and sometimes very much shorter.

If this was the only gain, it would be considerable, but the real gain is behind this; the positions furnished by the galactic co-ordinates are final; comparisons betwixt star catalogues will become immediate. To work out a proper-motion of a star to-day requires hours if not days of work, because of the fictitious movements impressed upon it. With galactic co-ordinates, the comparison will be the work of minutes, and will moreover yield the proper-motion referred to its natural plane.

One cannot but regret that in planning the great *Carte-du-Ciel* the advantages of a proper system of co-ordinates were ignored. Let us look at the difficulty which the system adopted leads to. To take, as an example, the Cape *Carte-du-Ciel* Catalogue, we learn from Mr. HOUGH's last report that it will fill eleven quarto volumes and give the positions of about 990,000 stars in all. At the same rate the complete sky *Carte-du-Ciel* catalogues will furnish the places of some 13,500,000 stars. These are all to be referred to the mean equator and mean equinox of 1900. If the catalogue is repeated, as is the implied intention, in another century (or less as I hope), and it is referred to its mean epoch, any comparison between the two catalogues will be extremely laborious because the effect of precession on the so-called standard co-ordinates is complex. But let us assume that instead of 13,500,000 stars there are only 8,000,000 catalogued and that each star can be effectively compared in ten minutes of time, then the complete comparison will occupy one man's full time for 555 years, and, at the moderate salary of £200, cost £110,000. I fear that there is a danger here in that the *Carte-du-Ciel* scheme is strangling itself so far as useful work goes by adding so enormously to its load of inertia. Had the places been referred to the galactic system by the use of galactic plate centers and secular co-ordinates, comparisons would be practically instantaneous.

There is, however, a saving clause. When the *Carte-du-Ciel* scheme was started in the 1880-1890's, astronomers tacitly assumed (forgetting PROCTOR's work) that each star moved on its own — was an individuality distinct from its neighboring stars; an assumption engendered by the known motions of the brighter stars then most studied. To-day it is known that stars are traveling in communities and that the number of these communities is not large; that they, perhaps, can be counted on the fingers of one hand; but it would not matter if there were one thousand communities—it is much easier to deal with one thousand communities than with 13,500,000 individuals; and it is also known that the number of large or erratic proper-motion stars is very restrained. Hence, the real value of the *Carte-du-Ciel* consists in its photographs or their enlargements; in fact, in the *Carte-du-Ciel* and not in the places of stars derived from it. Examination of these *cartes* taken at different dates by means of superposition and projection in an enlarging lantern or by a blink-apparatus (as made by Messrs. ZEISS) will at a glance discriminate those stars which are moving "out of community." Measures of these and of *a few* of those moving "in community" will give all the information as to these motions which is required. By this means instead of measuring on an average three hundred stars per square degree, about eight or nine will suffice. The saving from this point of view alone is forty-fold.

A superficial criticism is that the galactic plane is not rigidly marked on the sky. But is the equator? The former is defined by the galactic latitudes of the stars at the chosen epoch and at later epochs by such latitudes as will reduce the totality of proper-motions (freed from the effect of motions of the solar system) to a minimum. To this plane must be referred the equator and equinox of the Earth, and not *vice versa*. In the future, star-places will be determined solely by photography but to-day we are in a transition period and one of rivalry. But where the ultimate victory will be is not uncertain. If we look over Boss's Preliminary Star-Catalogue, we see that with hundreds of observations spread over a century, we may hope to know such a well-observed star's place, as determined with meridian instruments, with an accuracy of about ± 0".05 at the center of gravity of the observations, and of ± 0".1 forty years afterwards. Professor KAPTEYN, in measuring photographs of the *Hyades* group of stars,[1] finds an accuracy as great from one set of plates; whilst Mr. F. Slocum, in measuring the parallax of *Nova Geminorum* (2), finds a probable error of ± 0".007 from observations spread over less than one year. It might be objected that the photographic measures are differential measures, which are always more accurate than absolute measures, but it is probable that these differential photographic measures can be continued around the sky in belts and the triangulations closed with all possible accuracy. At the present time Professor H. H. TURNER is trying various methods of finding the absolute places of stars by photography at the University Observatory at Oxford. The results so far obtained are encouraging, but as might be expected with any new method, various difficulties arise and have to be combated. It is, however, quite doubtful if the probable error of a well-observed meridian star above given, $0''.05$, means anything, because, after all, it depends on the position of the equinox, a very elusive point indeed.

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[1] Groningen *Publications* No. 14.

I have laid the advantage of using galactic co-ordinates before astronomers in Circulars Nos. 2, 5 and 6 issued by the Union Observatory. In Circular No. 2, the necessary formulas are developed and tables given for the conversion of mean equatorial co-ordinates to invariable galactic co-ordinates for any year from 1750 to 1950, with a special table for the conversion of true equatorial co-ordinates to invariable galactic co-ordinates or *vice versa* for the current year 1913. The processes are illustrated by numerical examples.

The most thorough investigation of the position of the galactic plane was made by NEWCOMB and published in 1904 under the title "On the Position of the Galactic and Other Principal Planes Towards Which the Stars Tend to Crowd." Unfortunately, the principal galactic plane cannot be found very precisely because the Milky Way is a very irregular aggregation of stars, throwing out wisps and branches, whilst the zone of brightest stars is considerably inclined to it. NEWCOMB gives the following poles:—

	R. A.	Dec.
Galactic plane (omitting branch)	192°.8	+27°.2
Galactic plane (including branch)	191 .1	26 .8
Plane of Vth type stars	190 .9	26 .7

It is known that stars of the fifth type (bright-line spectra) are all close to the principal plane, but their number is small. It has further been assumed that the solar system is in the principal plane. But it is not a matter of great importance if the assumed position of the plane is in error so long as it is nearly correct, as any small error can easily be allowed for when the progress of astronomy requires. The total change in many thousands of years will certainly be less than the change in all the present star catalogues every fifty years caused by the fictitious precession of the stars.

Besides the position of the plane, it is necessary to adopt a departure point from which longitudes are to be counted, and it is obvious that this must be a fixed point. The point actually chosen is that one which in this age will make the longitude of the apex of solar motion—the direction towards which the Sun is moving—equal to 0°. This point is chosen because a considerable portion of the proper-motions of the stars is actually due to the solar motion through space and it renders the effect of this motion in a uniform manner, in that generally proper-motions so far as they are caused by the Sun's motion, tend toward 180° of galactic longitude. Here again a compromise has had to be made, because the apex of solar motion depends on the class of stars to which it is referred. I have adopted for 1900 the position of the apex recommended by Dr. CAMPBELL of the Lick Observatory,—namely, R. A. 18ʰ, Dec. + 30°—and for the plane, NEWCOMB'S determination, including the branch, so that we have—

Ascending node .	$281^\circ\ 6'\ 0''.00 + 4413''.57\,T - 6''.88\,T^2 + 0''.186\,T^3$
Inclination ..	$63\ \ 12\ \ 0\ .00 + 1967\ .18\,T - 4\ .56\,T^2 - 0\ .145\,T^3$
Departure point .	$23\ \ 35\ \ 27\ .26 + 432\ .40\,T + 22\ .46\,T^2 - 0\ .128\,T^3$

in which T indicates solar *centuries* after 1900, assuming as correct NEWCOMB'S variation of the Earth's equator and orbit.

In Circular No. 5, the advantages of using a fixed system of coordinates in planetary theories is insisted on, and for this fixed system, there is no reason why the galactic system should not be used. If anything, the simplifications which would thus be introduced into the planetary theories are more considerable than those already dealt with. At simplest, the motions of planets and comets are complicated, but this complication is vastly increased by adding onto their motions—motion in their orbits and of their orbits—other imaginary motions, as is done at present.

In Circular No. 6, it is shown that if even a precise daily ephemeris of a star in equatorial co-ordinates is required, which appears to be the most unfavorable case for the use of galactic co-ordinates, one can be easily and rapidly computed without any knowledge of the star's imaginary mean right ascension and declination; as an example, an ephemeris of ε *Orionis* is computed for the current year (1913).

Astronomers have been quite aware of the awkwardness of referring the stars and planets to rapidly shifting planes, and some attempts to get over the chief difficulties have been made. Thus, the late Dr. RISTENPART proposed that the equinox should be changed every twenty-five years, and he would call 1875, 1900, 1925, etc., normal equinoxes. He has published tables for the normal equinox of 1925. His idea would save some work, but not much; it is, in short, only a palliative. The astronomical ephemerides do something in the same direction. As an example, I will deal with the issue for 1915 of the celebrated *Connaissance des Temps*, which, as it proudly boasts, is the oldest astronomical almanac now published, as it first appeared in 1679 and has never suffered an interruption; besides this, it has always been brought up to date so punctually that it might also claim to be the youngest. For the Sun, the *Connaissance des Temps* furnishes the longitude and latitude for date and for the mean equinoxes and ecliptics of 1915 and 1920—three where one would do. Similarly for the planets, the heliocentric co-ordinates are referred to the Earth's true equinox and ecliptic of date, and to the mean equinox and ecliptic of 1920. For 732 minor planets the Gaussian Constants and their variations are given. It seems illogical to speak of constants varying; they really do not do so; nevertheless, 4,392 annual variations are specially computed for 1915. If galactic co-ordinates had been introduced, it is only three annual variations that would have been required—a saving of 4,389 out of 4,392. Lastly, for the stars, the elements of reduction are given for the mean equinox and equator of 1915 and also for 1920. And when one has got to 1920, the labor of Sisyphus will still go on, but the mountain gets a little steeper each time.

UNION OBSERVATORY, JOHANNESBURG, 1913 June 26.

CLASSIFICATION OF VARIABLE STARS.

By Sidney D. Townley.

In 1880 Professor E. C. Pickering proposed a classification of variable stars as follows:[1]

I. Temporary stars. Examples, Tycho Brahe's star of 1572, new star in *Corona*, 1866.

II. Stars undergoing great variations in light in periods of several months or years. Examples, *o Ceti* and *χ Cygni*.

III. Stars undergoing slight changes according to laws as yet unknown. Examples, *α Orionis* and *α Cassiopeiæ*.

IV. Stars whose light is continually varying, but the changes are repeated with great regularity in a period not exceeding a few days. Examples, *β Lyræ* and *δ Cephei*.

V. Stars which every few days undergo for a few hours a remarkable diminution in light, this phenomenon recurring with great regularity. Examples, *β Persei* and S *Cancri*.

This classification is restated, in somewhat different language, in the preface to the *Preliminary Catalogue of Variable Stars*, published by Harvard College Observatory in 1902.[2] Subdivisions of classes II and IV are suggested, but they are not used in the catalogue nor are they used or mentioned in the *Second Catalogue of Variable Stars*, published in 1906.[3]

So far as I know, this classification has not been used in any catalogue except those published by Harvard. Schönfeld, Chandler, and Gore used no classification in their catalogues.

In the *Catalogue des Etoiles Variables*, issued annually by the Bureau des Longitudes, a classification is used which differs somewhat from Pickering's. It is as follows:—

Type I. Variables of long period.
Type II. Variables of short period.
Type III. Variables of *Algol* type.
Type IV. Variables of antalgol type.
Type V. Variables of irregular variations.

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[1] *Proceedings of the American Academy of Arts and Sciences*, **16**, 17, 257.
[2] *Annals of Harvard College Observatory*, **48**, 94.
[3] *Annals of Harvard College Observatory*, **55**, 1.

In the *Katalog und Ephemeriden veränderlicher Sterne*, published annually in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, no classification is used in the catalogue part, but for convenience of reference four additional parts are given containing the various subdivisions of short-period variables, a term not now altogether applicable. These subdivisions differ from those of the two classifications mentioned chiefly by the fact that stars of the *β Lyræ* type are set off by themselves, a proceeding which is perfectly legitimate for the purposes of an ephemeris.

Mr. A. STANLEY WILLIAMS has recently proposed a new classification which he calls a natural system.[1] The classification is as follows:—

Order I. Binary or compound variables—
  a. *Algol* type, in which the variation is caused by eclipses, but the secondary minimum is either not apparent, or else is small in comparison with the primary minimum.
  b. *β Lyræ* type. Variation caused by eclipses, the secondary minimum being marked and equal, or nearly equal, to the principal minimum.
  c. *Cepheid* type—
    i. Stars like *δ Cephei*.
    ii. Stars of the exaggerated *δ Cephei* type of variation, termed "Antalgol" or "cluster type."
  d. Irregular short-period variables—
    i. Stars like *U Geminorum*, having some appearance of periodicity.
    ii. Rapid irregular variables, like RX *Andromedæ*, without definite signs of periodicity.

Order II. Long-period variables—
  a. *o Ceti* type.
  b. Stars like *o Ceti*, but having a pronounced double maximum.
  c. ?

Order III. Irregular variables—
  a. All irregular variables other than rapid irregular variables included under I, *d*, ii.
  b. *Novæ*.

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[1] *The Journal of the British Astronomical Association*, **23**, 133.

Although something may be said in favor of this proposed classification, yet on the other hand there are some points that may be urged against it. Much has been learned in recent years concerning variable stars, but there is perhaps some question as to whether or not we are yet in possession of sufficient knowledge concerning the causes of variation to enable us to work out a "natural" system.

The two fundamental statements upon which WILLIAMS bases his classification are both open to question.

A "The variability of all eclipse variables and all short-period variables of the δ *Cephei* type is due directly or indirectly to the revolutions of two or more stars around their common center or centers of gravity. In other words, we are in the presence of a binary or multiple system of bodies."

Since the above statement was written, Mr. HAROLD SHAPLEY has published two interesting papers[1] on the variables R[illegible] *Camelopardalis*, SZ *Tauri*, and S *Antliæ*, δ *Cephei* or ζ *Geminorum* types of stars, in which he shows that the variation in brightness of these stars can be satisfactorily explained on the hypothesis that they are rotating ellipsoids. If this should prove to be the true explanation, then they are probably not binaries at all and the statement quoted above would not be true.

B "Variables of long period, like *o Ceti*, are not due to the revolutions of the members of a binary or multiple system of bodies, but the variability is probably inherent in isolated bodies."

This may be true, but as Mr. WILLIAMS points out, "only a few long-period variables have had their radial motions investigated by means of the spectroscope," it would seem that further proof of this statement is desirable before it can be used as a basis of a classification of variable stars.

Some further points against the proposed system are as follows:—

1 When it becomes possible to classify variables according to the causes of variation, it will probably be necessary to give up the terms "long-period" and "short-period," yet Mr. WILLIAMS retains both these—one of them, to be sure, only as a sub-head. The variable which has the longest period, ε *Aurigæ*,

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[1] [illegible] Observatory *Bulletin*, **2**, 71; *Astronomische Nachrichten*, **194**, 353.

period 9,905 days, is not a "long-period" variable, but an *Algol* type.

2. Mr. WILLIAMS divides the irregular variables, some being under Order I and some under Order III. The velocity in the line of sight has been determined for but five irregular variables—α *Cassiopeiæ,* α *Orionis,* R *Coronæ,* α *Herculis,* and μ *Cephei.* Two of these prove to be binaries, one probably binary, and two not binary. Surely, this is small evidence upon which to divide irregular variables into binaries and not binaries. It may be of interest to point out that the two binaries, α *Orionis* and μ *Cephei,* and the one probably binary, α *Herculis,* do not show rapid fluctuations of light, and hence, according to WILLIAMS's classification, would *not* be classed as "binary irregular short-period variables," but would fall into the all-inclusive order III *a.* They are binaries, but would not be classed as binaries.

What right have we to classify U *Geminorum* and RX *Andromedæ* as binaries when neither their velocities nor the velocities of any stars of similar fluctuations have been observed?

Can we properly call a system a "natural" one in which it is necessary to provide a "negative" class into which are put all stars that do *not* fall into the other classes? WILLIAMS's Order III *a* is of this kind,—"all irregular variables other than rapid irregular variables included under I, *d,* ii."

3. WILLIAMS puts *Novæ* under Order III—irregular variables. Is this logical? A phenomenon in order to be either regular or irregular must be repeated. No *Nova* has, so far as known, made more than *one* appearance. These phenomena are all similar, a rapid increase of brightness followed by a more gradual decline, interrupted by minor fluctuations, into a state of former faintness or invisibility. What is irregular about this? If a circus comes to town but once in the lifetime of the oldest inhabitant is that an irregular phenomenon?

4. WILLIAMS has apparently departed as much as possible from the PICKERING classification. For instance, PICKERING put *Novæ* in Class I, while WILLIAMS places them at the end of his classification. Now, there is probably no particular reason why Professor PICKERING should have put *Novæ* first, but so long as he did so would it not be a wise policy, unless

there is some good reason for a change, to stick to that order of classification, with which most of us are familiar?

5. Any system of classification which calls for a division of sub-classes becomes a bit complicated and difficult to memorize.

I venture to suggest that the following modified PICKERING classification will answer all our present needs:—

I Novæ.
II Long-period variables.
III Irregular variables.
IV Short-period variables.
  a. δ *Cephei* type.
  b. ζ *Geminorum* type.
  c. Cluster or antalgol type.
V Eclipse variables.
  a. *Algol* type.
  b. β *Lyræ* type.
VI Magellanic Cloud variables.

Class II might be divided into sub-classes, perhaps as Mr. WILLIAMS has suggested or perhaps as Professor PICKERING has suggested. There is a fundamental difference between [illegible] Class III could also be subdivided.

If it should be thought desirable to give up the terms "long-period" and "short-period," then Class II might be called "non-uniform-periodic variables" and Class IV "uniform-periodic variables." In this case it would not be necessary to add a sixth class, as the Magellanic Cloud variables would then be put as a sub-class of IV, or perhaps come under the head of cluster type.

The objection to this terminology is obviously that eclipse variables are uniformly periodic, although not classed under that head. Class V might be dropped and put in as a sub-class of IV.

INTERNATIONAL MEETINGS OF ASTRONOMERS IN GERMANY.

By W. W. Campbell.

It was my duty and pleasure to attend the meetings of the International Solar Union at Bonn, from July 30th to August 5th, inclusive, and the meetings of the Astronomische Gesellschaft at Hamburg, from August 6th to 9th, inclusive. The incidents of the meetings divide naturally into two classes: those relating to the hospitalities extended to the members of the Solar Union and of the Gesellschaft, and those relating to the scientific proceedings. The formal meetings gave consideration to many interesting and important questions, but the hospitalities enjoyed were indeed remarkable in number, perfection of arrangements, and suitability. The personal side may well be referred to first.

The members of the Solar Union and their friends came together for the first time at a reception and banquet extended by the City of Bonn, on Wednesday evening, July 30th, in the large hall of the Lese-und Erholungs-Gesellschaft, on the shore of the River Rhine. Greetings of welcome were extended by His Excellency, the Bürgermeister of Bonn, and appropriate addresses were also made by the Rector Magnificus of the University of Bonn, and others.

The members of the Union and their friends were received in the garden of the historic Bonn Observatory by Director and Frau Küstner on Friday evening. An opportunity was at the same time afforded to inspect the instruments and current work of the observatory. The astronomers, recalling the exceeding fruitfulness of the Bonner Sternwarte under Argelander, Schönfeld, and Küstner, felt that they were upon hallowed ground. The reception will be remembered as a perfect and charming event.

We were the guests of the city of Cologne on the afternoon and evening of Saturday, August 2d. There were opportunities to see the cathedral very completely, including the great collection of treasures, the Rhine bridge, and the picture gallery. A magnificent banquet was tendered in the hall of the

Gürzenich, within the Rathaus. This was presided over by His Excellency, the Bürgermeister of Cologne.

Two excursions were arranged for Sunday, August 3d: first, an automobile excursion across country, in cars provided by citizens of Bonn, via the interesting volcanic regions lying southwesterly from Coblenz, and on to the city of Cochem in the Mosel Valley, where luncheon was served; thence down the Mosel Valley to its junction with the Rhine at Coblenz, and along the left bank of the Rhine to Bonn; and secondly, for those who preferred, a walking tour through The Siebengebirge. My choice fell with the motor excursion. Again, the detailed plans of the long trip, covering approximately 200 kilometers, were arranged and executed with German thoroughness; the roads were perfect; the views were such as only those who have motored in the Mosel and Rhine valleys can adequately realize, and the events made up a red-letter day. The pedestrians were likewise enthusiastic.

The crowning social event of the meetings was Professor KAYSER's excursion on the Rhine, from Bonn southward nearly to Coblenz and return, between the hours of four and ten Tuesday evening, August 5th. The spirit of KAYSER had pervaded the Bonn meetings, and all members who could possibly remain in Bonn until Tuesday night stayed over to accept his hospitality. The large passenger boat, which the host had chartered for the occasion, and the beautiful valley of the Rhine afforded a perfect setting for the memorable events of the evening. The members of the Union had lived an exceedingly strenuous life for six days, and now that the work was done, they were ready to enjoy the views, embracing picturesque villages, the Rhine terraces, and the ruined castles, which were always in sight; and the banquet, accompanied by speeches in all the languages represented and by songs in many of the languages, found everybody entering into the spirit of the occasion.

The members were daily indebted to Professors KAYSER, KÜSTNER, PFLÜGER, and EVERSHEIM, and to their assistants, for countless thoughtful acts relating to the success of the scientific meetings and to the comforts and pleasures of the social life. In response to the request of Professor PFLÜGER, the War Department of the German Government kindly arranged for an exhibition flight of a Zeppelin dirigible airship. The first session had just begun when a whirring noise attracted the attention of all, and a recess was taken in order that the delegates might observe the evolutions of the dirigible. The ship passed several times directly over the place of meeting and the exhibition was most impressive and greatly enjoyed.

The scientific meetings were held amid perfect surroundings in the rooms of the Physikalisches Institut of the university. The building had been completed and occupied only a few weeks prior to the meetings, and it includes what is probably the most up-to-date physical laboratory in the world.

The proceedings consisted almost wholly of the reports of the various committees and of discussions on the questions considered in the reports. On this occasion, as at former meetings, only a few of the reports were in printed form ready for distribution to the members, and as the reports relate largely to the technicalities of the subjects, it is not desirable to attempt here a comprehensive review of the proceedings. A feeling has existed that these reports should be completed, as nearly as possible, in advance of the meetings by correspondence methods, and that less should remain to be done when the committees come together at the stated meeting of the Union. Resolutions dealing with this phase of the subject were adopted, and it is hoped that the committee reports on future occasions may take final form at the first session of each committee, and be printed before formal presentation to the Union is made.

The Committee on Wave-Length Determinations was able to report extensive progress in the three-year interval since the preceding meeting of the Union. In this connection, we may mention Dr. BURNS's determination of standard wave-lengths in the visual region of the spectrum by means of the interferometer, under the guidance of Professors FABRY and BUISSON at Marseilles, and to his accurate determinations of wave-lengths for some 4,000 lines in the spectrum of iron by means of a grating spectrograph, under the supervision of Professor KAYSER at Bonn; and, further, the discovery by Dr. GOOS of Hamburg that the wave-lengths in the arc spectrum vary markedly, depending upon the part of the arc which serves as the source of light. On account of the Goos phenomenon, the committee recommended and the Union decided that

In the determination of standard wave-lengths a direct current of 220 volts should be used in strength six amperes for lines whose wave-lengths are greater than 4,000 Angstroms, in strength four amperes for lines whose wave-lengths are smaller than 4,000 Angstroms, and that the slit of the spectrographs should receive light only from a central section, two millimeters long, of an arc whose poles are separated by an interval of six millimeters, with iron electrodes 7^{mm} in diameter.

The Eclipse Committee reviewed the results of observations at the three unfavorable eclipses of the past three years, and offered information of value to intending observers of the total solar eclipse which will occur in Norway, Sweden, and Russia on the afternoon of August 21, 1914. About twenty institutions had already signified their intention of dispatching expeditions to various points on the path of totality. M. Donitch, of the St. Petersburg Academy of Sciences, has assumed the task of supplying intending observers with more detailed information concerning conditions along the eclipse path, and of advising as to the choice of observing stations, in order that parties may be well distributed to guard against a total failure from local clouds.

At the 1910 meeting, the Committee on the Classification of Stellar Spectra was appointed, with principal duty to consider and report upon the adoption of a system of stellar classification which should be suitable for universal use. The committee reported, and the Union adopted these two resolutions:

> That the Committee on the Classification of Stellar Spectra be asked to secure by co-operation the material necessary for the establishment of a system that can be recommended for permanent and universal adoption, and
>
> That pending the establishment of such a system the use of the Draper Classification be recommended in the form described in Volume 56, page 66 of the *Annals of the Harvard College Observatory*, except that wherever in accurate classification, a zero be added to letters not followed by other numerals, and that the absence of any numeral be taken to indicate only a rough classification.

To illustrate: In the so-called helium group, if the spectra concerned can be assigned definitely to their places, the letter B will be followed by the corresponding number, as in B0, B1, B2, . . . B9, but if the assignment is not definite, the approximate classification will be indicated by the letter B without accompanying numeral.

The Committee on Solar Rotation recognized that the differences in the results secured at Mount Wilson, Ottawa, and elsewhere, as yet unexplained, should receive consideration in the plans for further observations, and programs of observation having this end in view were recommended and adopted.

The report of the Committee on Solar Radiation was based largely upon the work of the Smithsonian Institution observers. Director ABBOT presented briefly the evidence which had led him to accept the conclusion that our Sun varies in radiating power as much as eight per cent in the course of a few days. He has further concluded that the output of solar energy increases slightly as the sun-spot areas increase, and *vice versa;* calling attention, however, to the apparent fact that temperatures at the Earth's surface decrease slightly with increasing sun-spot areas. The casual reader might conclude that these results are antagonistic, but this is not necessarily the case, for increased solar radiation may mean increased cloudiness in the Earth's atmosphere, with consequent reduction of mean temperatures at the Earth's crust. The subject is difficult as well as interesting, and I believe that ABBOT recognizes the need for further observation and investigation.

Interesting reports were presented by the Committees on Solar Prominences and on the Spectroheliograph. A new committee was organized to deal with all visual observations of the phenomena of the Sun's atmosphere.

About ninety astronomers and physicists attended the Bonn meetings. Of these, thirty were from German institutions and sixty were from other countries. America had the honor of providing the largest foreign attendance, as follows: ABBOT, Smithsonian Institution; Miss ALLEN and Miss WHITING, Wellesley College; AMES, Johns Hopkins University; CAMPBELL, and BURNS, Lick Observatory; E. C. PICKERING, Miss CANNON, and BAILEY, Harvard College Observatory; NICHOLS, Cornell University; PARKHURST and SLOCUM, Yerkes Observatory; PLASKETT, Ottawa Observatory; RUSSELL and SHAPLEY, Princeton University; SCHLESINGER, Allegheny Observatory; ST. JOHN, Mt. Wilson Solar Observatory; DOOLITTLE, SR., Flower Observatory; and STEBBINS, University of Illinois.

The next meeting of the Union will occur in Rome within the year 1916, probably in one of the spring months.

Nearly all the foreign astronomers at Bonn went to Hamburg to attend the twenty-fourth meeting of the Astronomische Gesellschaft. The attendance numbered about one hundred and fifty members—by far the largest in the history of the Gesellschaft. This was due to three principal facts:

1 Hamburg was selected as the place of meeting in order that members should have the opportunity of inspecting the recently completed Hamburg Observatory.

2 The time of the meeting was set to follow immediately that of the Solar Union meetings at Bonn.

3 The Gesellschaft was celebrating the completion of its first half-century of existence.

In Hamburg, as at Bonn, the importance of the personal element in astronomical progress was recognized. The Gesellschaft is fundamentally a co-operative organization, as it was founded, fifty years ago, with principal purposes to care for the asteroids whose discoveries were coming rapidly, for the undertaking of accurate meridian-circle observations of the stars down to slightly fainter than the ninth magnitude in zones assigned to various co-operating observatories, and to other similar purposes.

The city of Hamburg is a strong patron of the arts and sciences, and the hospitality extended to the visitors was exceedingly generous, appropriate, and well arranged.

The afternoon of Wednesday, August 6th, was devoted to the "Hamburger Sternwarte in Bergedorf." A special train took the astronomers and friends southeasterly about fifteen miles to the village of Bergedorf where the government of Hamburg, assisted by much private generosity, has built one of the most extensively equipped observatories in the world. The institution is located on the top of a ridge perhaps two hundred feet above the surrounding low-lying country. After luncheon in a large tent on the observatory grounds, several hours were devoted profitably to inspecting the large refractors, the large reflectors, the meridian instruments, and much auxiliary equipment. The domes, buildings, and instruments are all of the highest quality of modern German construction. A special article would be needed to do justice to the subject, and accordingly no description is attempted here. It is understood that the Hamburg government has undertaken to support its observatory on a generous basis; and a large staff of astronomers and assistants is already at work. The enthusiastic director, Professor Dr. SCHORR, has assumed a great responsibility, and in this he had the best wishes of all his guests of the day.

The educational department of Hamburg gave to the visitors on Thursday evening a splendid banquet, presided over by Senator Dr. von MELLE.

The whole of Friday was devoted to an inspection of the Hamburg harbor, thanks to the generosity of the Hamburg-Amerika Linie. The visitors, divided into two parties, steamed through the principal ramifications of the harbor, and were deeply impressed by the extensiveness of the harbor, the number of ships in action, the modern equipment for handling cargo, and the building of new ships of largest size. Luncheons were served on the ocean-going steamers "Blücher" and "Tabora."

Especially memorable was the private hospitality enjoyed on Saturday evening by many of the older astronomers, in the home of the Hamburg gentleman who has provided so many observatories with instruments of the highest precision.

The scientific sessions were opened by an address of welcome from Senator von MELLE, as a representative of the Senate of the Hamburg government. Professor SEELIGER, as President of the Gesellschaft, replied happily, with many references to the history of the Gesellschaft. He called attention to the interesting fact that whereas the Gesellschaft at its founding, half a century ago, was largely an organization of German astronomers, 56 per cent of the 426 members at the present time live outside of Germany.

Of the two astronomers who, as young men, had been chiefly instrumental in the founding of the Gesellschaft, one, Professor FÖRSTER, was present, in his eighty-first year, and the other, Professor AUWERS, was greeted in Berlin by a congratulatory telegram from Hamburg.

The four scientific sessions were concerned chiefly with the reports of committees in charge of the various departments of astronomical research fostered by the Gesellschaft.

By far the most extensive duty assumed by the Gesellschaft has been that of forming the Gesellschaft zones of accurate star positions. This work is now complete from the southern part of the north polar region covered by CARRINGTON'S catalogue of star places, southerly to declination — 18°. The zone comprised from between — 18° to — 23°, assumed by Algiers Observatory, is so nearly finished that the Gesellschaft announced the probable receipt of the results in manuscript within a few days. The Córdoba Observatory had undertaken the extension of the Gesellschaft zones southward to declination — 37°. It was announced, on the basis of Director PERRINE'S communication, that Part I of the extension, embracing — 22° to — 27°, was complete, and that Parts II and III, from — 27° to — 37°, would be ready for the printer in 1914. It is the hope that the sky from — 37° to the south pole shall be observed by photographic methods, rather than that individual meridian-circle determinations of star places shall be made. This seems to be a good place to report the existence of a strong feeling on the part of many astronomers present in Hamburg that the accurate positions of stars fainter than the eighth visual magnitude should in future be determined by photographic means, and that future work with meridian instruments should be confined to stars brighter than the eighth visual magnitude, especially with a view to obtaining extremely accurate positions of the brighter stars to assist in forming satisfactory systems of reference for the photographically observed fainter stars.

Reports upon the state of knowledge concerning variable stars and comets were presented. Other reports related to the publications *Der Astronomische Jahresbericht* and *Die Astronomische Nachrichten*, to investigations of asteroid orbits, and to plans for stellar parallax determinations from observations with meridian instruments. Reporting on the last-mentioned subject, GROSSMANN stated that his observations of *Arcturus* yield a parallax of 0".2,—in striking contrast with heliometer results approximating 0".07. A few members urged that extensive meridian observations for parallax should be carried on, but others felt equally certain that it would be unwise to devote any considerable fraction of astronomical research to this method of investigation at the present time, as the accidental and systematic errors seem entirely too large to give reasonable confidence in the results.

After the completion of reports on the stated subjects, there was opportunity for the presentation of fifteen or twenty short papers dealing with individual researches. In this connection, it might be said that several foreign members had held the erroneous view that there would be no opportunity for the presentation of individual papers, but that it was the custom to limit the scientific proceedings to the reports of the various committees and to the discussion of these reports. We take space for reference to three or four papers.

CHARLIER discussed the systematic proper-motions of the brighter stars. He was led to the conclusion that KAPTEYN's theory of two star-drifts is not satisfactory, but that SCHWARZSCHILD's ellipsoidal hypothesis of stellar preferential motions possesses a much higher degree of probability.

SEELIGER presented a paper on the fundamental conceptions of motion, space, and time, which would be equally appropriate in gatherings of astronomers and of philosophers. To mention only one of his conclusions, he expressed the view that, of the various geometrical conceptions existent, only the Euclidean system was applicable to astronomical problems.

BAILEY, of Harvard, read an interesting paper on the variable stars known as cluster variables—a subject to which his contributions have been so extensive that the subject may be said to be almost exclusively his own.

WOLF, of Heidelberg, showed many beautiful photographic spectra of nebulæ and of several especially interesting stars.

What was to me the most interesting paper was read by ROSENBERG, of Tübingen, on the application of the photo-electric cell to the photometry of variable stars. During many preceding months, astronomers were considering the work of KOCH on laboratory applications of the photo-electric cell as indicative of its great promise in stellar photometry. Consequently, we were prepared to learn from ROSENBERG's paper that the electric-cell photometer surpasses all other forms of existing photometers many-fold in sensitiveness. With this photometer attached to a five or six-inch refracting telescope, he was able to secure brightness measures of a star between the fifth and sixth visual magnitudes, in two minutes, with the probable error of a single determination not exceeding 0.002 magnitude. STEBBINS commented in generous spirit upon ROSENBERG's results by saying that the best he had been able to do with his selenium photometer, attached to a 12-inch telescope, was to secure the measure of brightness of a second-magnitude star, in one hour, with probable error 0.01 magnitude. Professor STRUVE commented that GUTHNICK, an assistant in the Berlin Observatory, was likewise applying one of the electric-cell photometers to the study of variable stars, and had met with considerable success. Granted that the accuracy claimed for this new form of photometer is approximately correct, it must be apparent to all students of variable stars that we are about to enter an exceedingly rich field of astronomical investigation; in fact, it requires no unusual stretch of imagination to foresee that this photometer may be as powerful a tool in the hands of astronomers as the spectroscope and photographic plate have been.

Although it is the policy of the Gesellschaft to hold meetings only every other year, on the average, it was decided that the twenty-fifth meeting should occur at St. Petersburg and the Pulkowa Observatory shortly following the total solar eclipse of August 21, 1914, which event will call many astronomers from many countries to Russia.

A large number of the astronomers and friends, especially of the foreign contingent, spent a delightful and profitable day, August 11th, at the Potsdam Observatory, as the guests of Director and Frau SCHWARZSCHILD. The Potsdam astronomers have always been prominent in the advance guard of investigators, and the administration of the second director promises to be as fruitful of results as was that of the first. The current researches of the observatory were illustrated extensively by means of photographs.

An event of unusual importance relates to the removal of the Berlin Observatory from the center of the city of Berlin to the summit of a low hill in the village of Neubabelsberg. The new location is about four miles from the Potsdam Observatory, on the side toward Berlin. Director STRUVE was able to dispose of the old site for a large sum of money, and part of the funds thus made available is providing the new observatory with a greatly enlarged and splendid equipment.

There is a large central building, to contain a refracting telescope of about 26-inch aperture, other smaller telescopes, library and working-rooms, offices and computing rooms, accompanied by other buildings to contain meridian instruments and a reflecting telescope of diameter between 40 and 50 inches. Excellent progress has been made with the buildings and instruments; the staff of astronomers and assistants has been greatly increased; and this institution should be one of the most fruitful of observatories. A small refractor, moved from the old observatory, is already securing notable results by virtue of a photo-electric cell photometer attached to its eye end. At the close of the Potsdam visit many astronomers went to Neubabelsberg and were most favorably impressed by what they saw.

I sailed homeward on August 12th, with the knowledge that German astronomy is as wide awake as German commerce and German education.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1913.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	Nov. 5,	$10^h\ 34^m$	A.M.	First Quarter..	Dec. 5,	$6^h\ 59^m$	A.M.
Full Moon ..	" 13,	3 11	P.M.	Full Moon	" 13,	7 0	A.M.
Last Quarter..	" 20,	11 56	P.M	Last Quarter .	" 20,	8 16	A.M.
New Moon ..	" 27,	5 41	P.M.	New Moon ...	" 27,	6 59	A.M.

The Sun reaches the winster solstice, the point farthest south from the equator, on December 22d, about 3 A. M. Pacific time.

Mercury is an evening star on November 1st, reaching greatest east elongation on that date. The elongation is an average one, 23° 34′, but other things conspire to make conditions for visibility very poor, and the planet sets less than an hour after sunset, making it practically impossible for naked-eye view. Eastern elongation in the autumn generally afford a poor opportunity for visibility of *Mercury* owing to the circumstance that the planet is a considerable distance south of the

Sun at this time, and this condition is accentuated by the fact that the planet on November 1st is at a point in its orbit as far as possible below the ecliptic, the apparent path of the Sun among the stars. After November 1st the planet rapidly approaches the Sun, passing inferior conjunction and becoming a morning star on November 22d. It then moves rapidly away from the Sun and reaches greatest west elongation on December 10th. By December 1st it rises nearly an hour and one half before sunrise, and this interval increases to an hour and three quarters during the month. It is therefore in good position for naked-eye view on any clear morning in the eastern twilight. On December 2d it is in conjunction with *Venus*, passing 1° 35′ north of the latter.

Venus is still a morning star, but is drawing closer to the Sun, and toward the end of December will not be an easy object to view. On November 1st it rises a little more than two hours before sunrise, and this interval diminishes to about forty minutes by December 31st. It will reach superior conjunction with the Sun on February 11, 1914.

Mars is now getting into good position for evening observation, rising at about half-after nine on November, and only a few minutes after sunset on December 21st. It is in the constellation *Gemini*, and up to November 27th it moves eastward about 4°. It then begins its westward or retrograde motion, moving about 8° up to December 31st, on a line somewhat to the north of its path when moving eastward. On December 31st it will be about 3° north of the position it occupied on October 21st. Comparison of the positions of *Mars* from October to the end of December with respect to *Castor* and *Pollux*, the principal stars in *Gemini*, will give a good idea of direct and retrograde motion of a planet, as *Mars* moves forward and back on lines not far south of the two stars. The planet will nearly double in brightness during the two months, and will reach its maximum at the end of December. On this last day of the year the planet will attain its minimum distance from the Earth, although it will not reach opposition until January 5, 1914. The present opposition is by no means a favorable one, the least distance from the Earth being about fifty-eight million miles, while the distance at the opposition of 1909, September 24th, was only a little more than thirty-six millions. This makes the brightness of *Mars* at the present opposition scarcely more than one third that which it had at the opposition of 1909. The distance of *Mars* from the Earth at the next two oppositions will be a little greater than for the present opposition, but after these the opposition distance will gradually diminish until the opposition of August 28, 1924, when the least distance will be less than that of 1909.

Jupiter is still an evening star, but is gradually drawing quite close to the Sun. On November 1st it sets a little before nine o'clock, and on December 31st at a little before six, only a little more than an hour after sunset. Owing to its great brightness, however, it will be an easy object to see until after the close of December. Its motion among the stars is quite rapid, from *Sagittarius* toward *Capricorn*, about 13°.

Saturn is in fine position for observation. On November 1st it rises about two hours after sunset and comes to opposition on December 7th, when it is above the horizon practically the entire night. During the two months it moves westward about 5° in the constellation *Taurus*, and at the end of December is about 4° east and the same distance north of *Aldebaran*, the brightest star of the constellation.

Uranus is in the western sky in the evening, a little higher up than *Jupiter*. It sets at about 10:30 P. M. on November 1st and at about 7 P. M. on December 31st. It moves a short distance eastward in the constellation *Capricorn*, reaching by the end of December about the same position it held during the late summer.

Neptune rises about 10 P. M. on November 1st and at about 6 P. M. on December 31st. It is moving a little westward in *Gemini*.

NOTES FROM PACIFIC COAST OBSERVATORIES.

The 100-Inch Telescope.

During the summer considerable progress has been made on the plans for the 100-inch telescope. On Mount Wilson the foundations for the telescope building and dome were finished in July and work was begun on the great pier to support the instrument. This is now nearly completed. At its base the pier measures about 20 by 40 feet and its height is 33 feet above the ground level. The top of the pier is extended on all sides into a circular floor 52 feet in diameter, supported by heavy reinforced-concrete brackets, and from this floor a circular wall rises to the level of what will be the main floor of the steel building and dome. Provision is made in the inside of the pier for a room in which to silver the large mirror and for a water-storage tank to be used in maintaining a temperature control. At the south of the large pier is a long extension upon the face of which will be mounted spectrographs and such other apparatus as will be used with the telescope in the coudé form.

The plans for the telescope building and dome have been completed by D. H. Burnham & Co. of Chicago, and contracts for at least a portion of the work will be let within a short time. The diameter of the building will be about 100 feet and the height of the top of the dome 105 feet. The dome is designed to have a double roof of sheet iron with an intervening air space of about two feet, and louvres are arranged at the top of the dome to allow of the escape of the heated air. This plan has proved successful in the case of the 60-inch reflector. A shutter opening 20 feet in width is provided for the telescope, and because of this great width the construction of the dome is necessarily unusually massive. The shutter is divided vertically and consists of two portions, which move on horizontal tracks at the top and bottom. Rubber or hair cushions will be used along the faces of the two sections of the shutter to make it as nearly as possible airtight.

The design of the telescope mounting has advanced rapidly, and at present most of the general drawings are essentially complete. Detailed drawings of the north and south pedestals and the mercury tanks and floats have been sent to the Fore River Shipbuilding Corporation of Quincy, Massachusetts, which will build the more massive parts of the mounting. Castings have already been made for the two pedestals and one of the two mercury tanks. The most difficult part of the instrument from the point of view of design is probably the large polar axis and fork within which is swung the tube of the telescope. This is built up of structural steel and will be rectangular in shape, about 32 feet long and 16 feet wide. The fork will be made in four sections and will be bolted together in place on Mount Wilson. These sections will be among the heaviest parts of the telescope mounting, as each section will weigh about seven tons. The large declination bearings will be built into the side members of the fork, the steel castings forming the cases for the bearings, being riveted to the structural steel of the fork.

Work has been progressing steadily on the 100-inch mirror and recent tests have shown a figure which is very nearly spherical and with but a small amount of astigmatism. Zonal errors have been reduced greatly, and the parabolizing of the surface will be begun in a few weeks, it is hoped. A considerable amount of work has been done on the 60-inch plane mirror, which will be used in testing the 100-inch mirror during the work of parabolizing. With the edge support now in use, no evidence is found of differences of flexure along different diameters of the mirror. W. S. ADAMS.

MOUNT WILSON SOLAR OBSERVATORY.

STELLAR SPECTROSCOPIC NOTES.

Observations of the Companion of Rigel.—Four photographs, with low dispersion of the spectrum of the seventh-magnitude companion of *β Orionis* indicate that its spectrum is identical with that of the principal star. The difference in brightness, as determined by the Harvard observers, is 6.5 magnitudes, and the identity of the spectra of two stars, which almost cers form a physical system and which differ so greatly in ute luminosity, is rather a remarkable fact.

e mean radial velocity given by the four plates is $+ 20^{km}$, value in close agreement with the value of $+ 22^{km}$ found the center of mass of the spectroscopic binary system to h the principal star belongs. The four plates show a mod te range, but the fact that the star is a very close visual ry makes the interpretation of the variation as a real ge in velocity rather doubtful. The agreement of the velocities of the bright star and its companion make ysical connection very probable.

me Radial Velocity Results.—Two spectrograms of the known parallax star Groombridge 34 ($\alpha = 0^h\ 13^m$), mag e 8.2, show that the real motion of this star is almost s at right angles to the line of sight. The radial velocity n by the two plates is $- 1^{km}$. The spectra type of this r is Ma.

ee spectrograms of the star Lalande 15290 ($\alpha = 7^h\ 48^m$), gnitude 8.2, gives the following values of the radial velocity:

$$\begin{array}{r} -\ 247^{km} \\ 241 \\ 239 \\ \hline \text{Mean}\ -\ 242^{km} \end{array}$$

s is the largest radial velocity of any star so far observed The motion in space, assuming the values for proper n and parallax collected by Kapteyn, is 316^{km}. The trum of the star is G0.

the *Astrophysical Journal* for April, 1912, the approxi te radial velocities were published for two stars of high ty These were Lalande 5761 ($\alpha = 3^h\ 3^m$), magnitude and Lalande 28607 ($\alpha = 15^h\ 38^m$), magnitude 7.3. The s were classified as F and A respectively. Recently we obtained a photograph with the Cassegrain spectrograph ande 5761, which is of much better quality, and which s that this spectrum must also be classified as A and is, t almost identical with that of Lalande 28607. In both s, however, the spectrum is peculiar in that λ 4481 is either t or extremely faint, while the great strength of the hydrogen lines and the presence of the principal arc lines of iron as faint absorption lines point to a normal classification of about A5. It is a singular coincidence that two stars, both of peculiar but very similar spectra, should be characterized by such large velocities. The single spectrogram of Lalande 5761 gives a value of — 144^{km}, while four spectrograms of Lalande 28607 give — 170^{km}.

The Spectra of Some Individual Stars in the Hercules Cluster.—Two photographs were recently obtained by Mr. PEASE of the spectrum of the *Hercules* cluster (Messier 13), using a small slit spectrograph at the primary focus of the 60-inch reflector. The exposures were 21 and 22 hours respectively, and the slit width was twice as great for the second exposure as for the first. The spectrograph is mounted in the opening of the double slide plate-holder regularly used for direct photography, so that very accurate guiding is possible. As a result the spectra of individual stars appear on the photographs. Of these it has been possible to classify six upon the first photograph and thirteen upon the second, or a total of nineteen separate stars, since the slit was set at two different positions for the two exposures. Using as a unit five divisions of the Harvard scale, the stars are classified as follows:—

A_0	2
A_5	5
F_0	2
F_5	8
G_0	2

Perhaps the two most important features of these results are: First, the absence of any stars of very late types of spectrum; second, the fairly regular succession of the spectra, agreeing with what is generally considered the order of stellar development. It is also clear that conclusions as to the spectral types of the stars in clusters must be based upon photographs showing the individual stars. W. S. ADAMS.

MOUNT WILSON SOLAR OBSERVATORY.

NOTE ON THE GEGENSCHEIN.

Doubtless many, whether amateurs or professional astronomers, have never seen this very difficult object, and a word or two as to its history and appearance may not be out of place.

The Gegenschein, or zodiacal counterglow, is an exceedingly faint luminous patch some ten to twenty degrees in diameter, which can be made out by a keen eye at the point directly opposite to the Sun. It was first definitely observed by Brorsen about the middle of the last century, and has since been systematically observed by a number of astronomers, in particular by Professor Barnard, who has followed it regularly for twenty years.

Professor Barnard describes it as, in general, quite easy to see, and his observations on its position are most accordant; its central point appears to be always exactly antipodal to the Sun in the sky. It is, of course, useless to attempt to see the Gegenschein from a position in or near a brilliantly lighted city, or when the Sun's antipodal point falls in or close to the Milky Way. One member of the Lick Observatory staff finds no difficulty in always picking up the appearance; for my own part, I personally find it a very difficult object. Sometimes I can make it out without any trouble, while at other times, with conditions fully as favorable, I cannot see it at all.

A great many theories have been put forward to explain the cause of this faint luminous patch, none of which are perhaps entirely satisfactory. Its appearance changes at different times of the year; in September and the first part of October it is large, round, and distinct. About the middle of October Professor Barnard finds that it apparently shrinks to a mere condensation on a zodiacal band extending a long distance along the ecliptic. The fact that it is frequently best seen in a sky that is not too pure has always given Professor Barnard the impression that it is in some way connected with our own atmosphere, though he admits that the absence of any sensible parallax in the appearance militates against this view.

Mr Evershed suggested that it might be a quasi-tail to the Earth, produced by the escape of molecules of hydrogen and helium from the Earth's atmosphere, which are driven off in a direction opposite to the Sun in a similar manner to the formation of a comet's tail. Here, also, the absence of any parallactic effect forms a strong objection.

Professor Searle suggested that it might be due to finely divided matter in the asteroid zone. At the point opposite to the Sun such small bodies would not only be nearer to the

Earth, being in opposition, but would also exhibit their full phase effect in the reflected sunlight which they would send to us; both causes would tend to give a maximum of light opposite the Sun—a Gegenschein. The fact that this phenomenon is frequently fairly well defined and distinct, with no gradual shading off on each side of the antipodal point, makes this theory less probable.

One of the most interesting of the theories of the Gegenschein is the meteoric theory, first suggested by GLYDEN and later by Professor W. H. PICKERING, but independently derived and thoroughly worked out by MOULTON. The essentials of this theory are, in brief, as follows: It is mathematically possible that bodies of infinitesimal mass, as a special case in the Problem of Three Bodies, should congregate in the neighborhood of a point exactly opposite to the Sun and about 900,000 miles from the Earth. The orbits of these small bodies would not be stable, doubtless they would make a few revolutions about this critical point, and then pass on; on the average, as many would be captured for a time as those which escape, but the effect would be that of a condensation, and MOULTON'S theory is that the Gegenschein is due to light reflected from this swarm of temporarily captured meteoric particles. As it has been estimated that ten million meteors enter the Earth's atmosphere daily, the total number of such small particles in the solar system must be enormous.

Hopeless as it may seem, *a priori*, there is just a possibility that this theory might be tested. If the theory is true, the great majority of these particles must be small; a failure to photograph them, then, would not necessarily disprove the theory. However, it is probable that an object one hundred feet in diameter would leave a faint trace on a Crossley negative in an exposure of two hours, if the body were at a distance of 900,000 miles and if its albedo were equal to that of the ordinary asteroid. Were a meteor of this rather unusual size to be caught in this critical region, its value as a laboratory example of a case in the Problem of Three Bodies would be very great. Though a successful result seemed most improbable, I thought it worth while to make the test. The photographs are quite difficult to secure; the average motion of the hypothetical meteoric bodies would be about 145 seconds of arc per hour along the ecliptic. As the maximum range of the moving-wire system in the Crossley guiding eye-piece is somewhat less than 100 seconds of arc, it was necessary to guide by means of the long finder, whose focal length is approximately that of the main instrument, with an attached micrometer: the bodies would move one second of arc in about twenty-four seconds of time. Two plates were taken on September 3d, with exposures of one hour each; the second check plate is necessary to be able to reject the small flaws, very faint and frequently startlingly like a stellar image, which are too often found on commercial plates. The region photographed was almost precisely at the Sun's antipodal point. The result was entirely negative; no certain trace of any such body was found.

H. D. CURTIS.

NOTE ON COMET *b* 1913 (METCALF).

The second comet of the year was discovered by METCALF, of Taunton, Massachusetts, the night of September 1st, in the constellation of the *Lynx*. Its motion is northward and westward. From observations by Dr. AITKEN of the Lick Observatory, taken on the 2d, 3d and 4th, the orbit was computed by Miss SOPHIA LEVY and myself.

The comet is moving in a plane inclined 143° to the plane of the ecliptic. Its nearest approach to the Sun was September 14th, at a distance of 126,000,000 miles. At the present time it is approaching the Earth and becoming brighter. The closest approach to the Earth will be about 50,000,000 miles, at the end of September. It will continue to increase in brightness until about that time, when it will diminish in brightness very rapidly. It will probably not become bright enough to be visible to the unaided eye.

The comet will continue its northward journey until it is within about 12 degrees of the pole, when it will start southward through *Cepheus*. It is at present in *Camelopardolus*.

The elements of the orbit and a short ephemeris have been published in *Lick Observatory Bulletin*, No. 235.

R. T. CRAWFORD.

September 15, 1913.

NOTE ON COMET *c* 1913 (NEUJMIN).

This object was apparently discovered by M. NEUJMIN at the Pulkowa Observatory on the night of September 5, 1913, but the first announcement of its discovery came to the Lick Observatory in the form of a telegram giving an observation by GRAFF, at Bergedorf, Hamburg, on September 6th.

The first observation was secured here on Monday night, September 8th. In the moonlight, the object showed very little resemblance to the ordinary comet. It had the appearance of a star of magnitude 11 or 11½, with no more than the merest suspicion of nebulosity. Indeed, it was only detected by its motion. On later nights, as the Moon grew brighter, no trace of nebulosity could be detected either with the 12-inch or with the 36-inch telescope. Last night, however, September 22d, when examined with the 36-inch against a dark-sky background, a faint brushy nebulous extension, like a short tail, was seen to extend three or four minutes of arc toward the southeast from the nucleus, in about 145° position-angle. The light of the head was practically entirely concentrated into the very sharp stellar nucleus of about 11.5 magnitude. At moments this nucleus seemed to be surrounded with an exceedingly feeble nebulosity, perhaps half a minute of arc in diameter.

This comet thus contrasts very strongly in appearance with the one discovered by METCALF on September 1st. METCALF'S comet is a round, condensed nebulous object, which, except that it is fainter, strongly resembles the appearance of the globular star cluster in *Hercules*, as seen with a small telescope.

From observations on September 6th, 7th and 8th, EINARSSON and NICHOLSON, at the Students' Observatory, Berkeley, computed an orbit for NEUJMIN'S comet, by LEUSCHNER'S short method. Even on the basis of this short observed arc, it was found that the orbit was elliptic, a parabola leaving residuals far too large to be due to errors of observation. Repeating the computation on the basis of a seven-day arc (observations of September 6th, 9th and 13th), the same computers find that the orbit is an ellipse with a period of 25½ years. The comet has already passed the points of closest approach to both Sun and Earth, and is now about 61,000,000 miles distant from the latter. It is in the constellation *Pisces* and will move north and west into *Pegasus*. R. G. AITKEN.

September 23, 1913.

CROSSLEY REFLECTOR IMPROVEMENTS.

The original Crossley mounting and dome provided for the observer's position at the eye end of the telescope by means of an elevating platform raised and lowered by hand. Due to certain deficiencies in construction, this elevating platform was found inconvenient in actual use, and it was necessary to discard it at the time the new mounting for the telescope was installed, using instead of a pair of ladders in connection with two sliding platforms resting upon an elevated floor. The use of this system has been found to entail great strain and inconvenience on the part of the observer, particularly in long exposures; in many positions of the telescope, especially for objects north of the zenith, the close and exacting work of guiding is carried out only at the cost of great strain and fatigue on the part of the observer. To render the instrument more efficient and easier in use a number of improvements have been designed, which are now being installed. These improvements comprise:—

An elevating platform, four by ten feet in size, raised and lowered by a one-half horse-power electric motor, so as to give the observer convenient access to the guiding eye-piece in any position of the telescope. This platform is carried on a strong iron framework, which is attached to the dome and revolves with it; on the platform will be carried the controllers for the motors which rotate the dome and elevate the platform.

The slow motion in right ascension is at present controlled by an endless cord; for this there will be substituted a small electric motor, with a switch at the eye end.

The hand clamps in right ascension will be supplanted by electric clamps, controlled from the eye end of the telescope.

The driving system of the Crossley is rather unique, in that it consists of two sectors of about eight feet radius; one of these is reversing while the other is driving, and this has in the past necessitated that the observer leave his guiding twice each hour, once to stop the reversing sector at the end of its travel, and once to change from one sector to the other by operating the hand clamps and shifting certain levers connected with the gear train in a certain specified order. An automatic electrically operated gear-shifting mechanism has been designed, and is in process of construction, which will make these changes at the proper time, with no attention from the observer.

H. D. CURTIS.

CORRECTION.

In my note on the unit of stellar distance in the August number of the *Publications* I regret that I inadvertently grouped the term *siriometer* with other terms which have been suggested as names for the distance corresponding to a parallax of one second of arc. The name *siriometer* was introduced by Professor C. V. L. CHARLIER, and is the distance equal to one million times the mean distance of the Sun from the Earth. It thus is almost identical with the term *Siriusweite* (the distance corresponding to a parallax of 0.2 seconds of arc); the parallax of a star at a distance of one *siriometer* would be equal to 0″.206 +. It has the advantage that it is a definite and easily remembered multiple of the astronomical unit.

H. D. CURTIS.

REDISCOVERY OF WESTPHAL'S PERIODIC COMET.

The fourth comet of the year was discovered on September 26, 1913, by Mr. DELAVAN, at the La Plata Observatory, Argentina. This proves to be identical with WESTPHAL'S comet of 1852, which was expected to return to the neighborhood of the Earth this year, as the computed period was about sixty-one years. Only three comets of longer period than this have so far been observed at a second return to perihelion. These are HALLEY'S comet, PONS-BROOKS' comet (1812-1883), and OLBERS-BROOKS' comet (1815-1887). In 1852, WESTPHAL'S comet was, for a time, visible to the naked eye, though not a great comet.

R. G. AITKEN.

GENERAL NOTES.

Photography of the Aurora.—An account is given in *Nature* for August 7th of the excellent results which have been secured by Professor CARL STÖRMER in auroral photography. The data secured by the expedition will form a very valuable extension to the important results secured photographically by Dr STORMER in 1910 at the same station. From a discussion of the negatives secured at that time the average height of the auroral formations was found to be about seventy-five miles, though some formations were observed as high as two hundred miles. From February 28th to April 1st, 636 pairs of simultaneous photographs of the aurora were made at the two stations selected, Bossekop and Store Korsnes, in northern Norway, the latter station being nearly seventeen miles north of the former. Of these photographs, 450 pairs are said to be very satisfactory, and will furnish material to compute with a large degree of accuracy the form, position, and altitude of all the principal kinds of aurora borealis. At the same time exposures were made with a prismatic camera, showing superposed images of the aurora corresponding to the different spectral lines. A kinematograph was also successfully employed to obtain successive photographs showing the rapid changes which take place in form of the auroral streamers.

Dr KEIVIN BURNS has received an appointment in the Bureau of Standards, Washington, D. C. Dr. BURNS was for several years assistant in the Lick Observatory, and for two years past has held the Martin Kellogg Fellowship. He has spent the major portion of the two years in carrying out several important pieces of research work in spectroscopy in the physical laboratories at Bonn under the direction of Professor KAYSER, and at Marseilles under Professors FABRY and BUISSON.

Dr. SEBASTIAN ALBRECHT, formerly assistant astronomer at Lick Observatory and first astronomer at Córdoba, Argentina, has been appointed astronomer at the Dudley Observatory, Albany, N. Y.

The Minister of Public Instruction of Argentina has authorized the preparation of an expedition from the National Observatory at Córdoba, in charge of Director PERRINE, to observe the Russian total solar eclipse of August 20-21, 1914. The expedition will be composed of three members of the Córdoba staff, with an extensive equipment of instruments, and will be located in southern Russia, not far from the Black Sea. It is expected that the expedition will be joined by astronomers from the Berlin, Potsdam, and Königsberg observatories.

An Arithmetical Curiosity.[1] — What is the largest number that can be expressed by three digits? The answer is, of course, 9^{9^9}; it is a number of inconceivable and appalling magnitude, compared with which the huge numbers that we meet in sidereal astronomy fade into absolute insignificance: 9^9 is 729^3, which is easily found to be 387,420,489. We have to multiply the logarithm of 9 by this figure in order to obtain the logarithm of 9^{9^9}. The number represented by this arrangement of three digits will contain 369,693,100 digits. The first twenty-eight of these figures will be 428,124,773,175,747,048,-036,987,115,9, and the last three figures of the number will be 289. A knowledge of only thirty-one figures out of over three hundred million may seem trifling, but in reality the error involved in taking all the remaining figures as zeros is only one part in a thousand quadrillions. If the number were printed with sixteen figures to the inch, it would extend over 364.7 miles; it would fill thirty-three large volumes of 800 pages and 14,000 figures to the page. There are more than twice as many digits in the number as there are letters in the whole of the Encyclopædia Britannica. . . . What is the smallest thing we have yet thought of? Probably an electron is about the right answer. Call it A. And what is the largest? Dr. CROMMELIN takes a million light-years as the largest distance of a star yet mentioned seriously. Describe a platinum sphere of this radius, and find the number of electrons in it; there will be ninety-one figures in the result. Take this huge sphere B *as an electron* and find a new platinum sphere C, which shall be in the same relation to it as that just sketched (B to A). Take C as an electron and find D, with the same ratio. Take D as an electron and find E; take E as an electron and find F. E will contain fewer, and F more electrons, than this enormous number.

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[1] Abridged from Dr. CROMMELIN'S paper of this title in the *Journal of the British Astronomical Association* for May, 1913, and from *The Observatory* for July, 1913.

Longitude Determinations by Wireless Telegraphy.—According to a circular issued by Captain J. L. JAYNE, Superintendent of the U. S. Naval Observatory, there is to be conducted, between October 1, 1913, and April 15, 1914, "a determination of the difference of longitude between the U. S. Naval Observatory in Washington and the Paris Observatory in France, utilizing radio signals from the Naval Radio Station at Arlington and from the Eiffel Tower Station in Paris."

It is planned that the astronomical work shall be done with instruments of high precision, every precaution being taken to determine the clock corrections "with extremely small accidental and systematic errors, either instrumental or personal."

The invitation is extended to any observatory within radio-receiving distance from Washington to determine its longitude relatively to that of the Naval Observatory, by installing a radio-receiving apparatus.

A New Reflecting Telescope for Canada.—The powers of astronomical mirrors have developed so extensively in the last decade that many new reflectors have been and are being constructed. The greatest success of a decade ago was attained with the Crossley reflector and the most recent is that of the Mount Wilson 60-inch. The mammoth mirror of the present day is the 100-inch to be mounted soon on Mount Wilson. Reflectors have been set up at Yerkes, Harvard College, Allegheny, Detroit, and Lowell observatories in the United States, and at Arequipa, Santiago de Chile, and Helwan, Egypt, and new ones are being designed for the University of Illinois and the Dominion of Canada. That for Canada will be as large or larger than the largest now of demonstrated success—namely, 60 or 70 inches.

It is the intention of the Dominion Government to spend $50,000 for the new instrument and to locate it at an altitude of a few thousand feet, probably in or west of the Canadian Rockies. Bids for construction have been requested from builders in Great Britain and the United States. Specifications have been laid down by Dr. W. F. KING, chief astronomer, and appear in the *Journal of the Royal Astronomical Society of Canada*, **7**, 216. Many of these specifications will be of interest to those who are interested in astronomical work. Dr. PLASKETT, of the Dominion Observatory, has visited California Observatories to inspect their reflectors and Mr. HARPER has been searching for a site in Western Canada, investigating in particular the "seeing." In this connection, he recently visited Mount Hamilton.

The principal work of this telescope will be that of spectroscopic observation for which the telescope will be used in Cassegrainian form, like the D. O. Mills reflector at Santiago de Chile, the spectrograph being attached below the primary mirror. The telescope will also be used, like the Crossley and 60-inch reflectors, for direct photography at the primary focus, or at the Newtonian focus at the side of the upper end of the tube, or at the Cassegrainian focus below the mirror.

According to the specifications, the mirrors shall be cast of hard crown glass, free from large defects and strains and thoroughly annealed. The diameter of the large mirror is to be five or six feet, and that of the small mirror about twenty inches. The thickness of the glass for the former is to be at least eight inches. The focal length of the primary mirror will be twenty-five or thirty feet and that of the Cassegrainian combination ninety or more feet. The optical surfaces shall be of the highest quality and figuring, and shall be tested by the Foucault or knife-edge method. The tests shall not show variations of more than a hundredth of an inch from the theoretically computed values of the radii of curvature of different zones. The artificial star used in the testing shall be formed by the condensation of the light of a powerful electric arc on a small hole not greater than two thousandths of an inch in diameter. Constant temperature shall be maintained during the testing. The Hartmann test shall be provided for if required. The tests shall finally be performed and the results approved by the representative of the government. Flat mirrors shall be provided for the Newtonian form of the telescope. Eye-pieces shall be provided for the Newtonian and Cassegrainian focus. Guiding eye-pieces shall be provided with the double slide plate-holder for direct photography. Two four-inch finders shall be fixed to the lower end of the tube. One seven-inch finder of long focus shall be provided.

The mounting is to consist of a long polar axis supported on separate columns and of a declination axis located between the bearings. The tube will be mounted on the declination axis as close as possible to the polar axis. This form of mounting is like that of the Melbourne, the Paris, and the Ann Arbor reflectors. The supporting piers shall be of cast iron, provided with the usual means of adjustment in altitude and azimuth. All bearings shall be roller bearings, running in bearing sleeves of hard steel ground with greatest accuracy. Hand wheels for quick motion shall be provided on the piers and the setting circles shall be arranged so as to be conveniently read from these hand wheels. The right-ascension circle shall be given motion at the sidereal rate so that the setting may be made directly from right ascension. Quick motion in declination shall also be given by an electric motor. Slow motions in right ascension and declination shall be effected by means of electric motors, controlled by switches which may be held in the hand of the observer either at the upper or the lower end of the tube to enable the fine setting and guiding to be done at the finders and guiding eye-pieces.

The telescope tube shall consist of a closed central section of cast iron and an upper section of skeleton construction, which shall be as light as possible consistent with rigidity. The flexure shall not exceed one eighth of an inch when the tube is horizontal. The upper end of the tube shall be so designed as to allow convenient change from one form of telescope to another—that is, from Cassegrainian to Newtonian or to prime focus observation. The secondary mirror, which will be nearly twenty-three feet above the primary mirror, shall be held tightly without constraint in its cell, but easily movable for adjustment in collimation and for focusing. The focusing shall be effected by rods and gears extending to the lower end of the tube. The upper end of the tube must rotate for proper position in guiding. The mirror cell, which shall be of cast iron, containing a system of counter-weights to support the mirror, will be attached beneath the central section. A ring three feet in diameter will be cast on to the bottom of the cell, which will allow for attaching and rotating the spectrograph. The frame holding the spectrograph may extend as much as eight feet below the mirror cell, but the lower end of the spectrograph frame shall not exceed one-half of the diameter of the upper end. The driving clock shall have gears, finely ground and without any periodic error. The driving worm and wheel shall be cut as truly as possible and finished by grinding. A system of wiring for illumination of circles, guiding eye-pieces, and for quick- and slow-motion motors and wires for the spectrographic apparatus shall be designed and installed without bearing rings or brushes.

For the purpose of transportation, no piece of the telescope shall weigh more than five tons. The telescope shall not be considered completed until it operates to the satisfaction of the representative of the government.

This instrument should prove to be of great capacity in performing its contemplated work. G. F. P.

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NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand will permit, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the Chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished to authors at cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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THE ELECTRIC-CELL PHOTOMETER.

BY W. W. CAMPBELL.

The spectroscope and the photographic dry-plate are very prominent amongst the astronomer's tools, and it is always a pleasure to acknowledge that the physicists and chemists discovered their fundamentals and made the first applications. The physicists are now developing another instrument which may be as important to astronomers as the spectroscope has been.

Studies in the conduction of electricity through gases led to the invention of the photo-electric cell by ELSTER and GEITEL. In its elements this cell consists of a glass bulb, a section of whose inner surface is coated with a deposit of an alkaloid metal, such as potassium or sodium, which contains only a very minute quantity of a suitable gas; and from whose coated and non-coated interior sections lead off, respectively, the two wires of an electric circuit. If the cell is in absolute darkness, no current will pass across the gap in the cell between the terminals of the circuit wires; but if a faint light is permitted to fall upon the alkaloid surface, the rarified gas in the cell becomes a conductor and permits current to pass between the terminals. The quantity of current passing is a function of the illumination; and, conversely, the strength of the current, as measured by an electromer in the circuit, or by other means, is a measure of the intensity of the illumination.

KOCH of Munich has made some wonderful applications of the electric cell to laboratory photometry: reproducing automatically, on a large scale and with great accuracy, the intensity curves of photographic spectra; even giving strong encouragement, and almost the assurance, that the accurate positions of poorly defined spectral lines can be determined by this method. KOCH's papers can be found in Wiedemann's *Annalen der Physik* of the past year.

Professor KEMP of the University of Illinois (a colleague of Professor STEBBINS of selenium photometer fame) published a valuable paper in the *Physical Review,* April, 1913, on those features of electric cells which seem to concern their use as the basis of sensitive photometers. By experimentation with cells coated respectively with sodium, potassium, rubidium and cæsium, and containing hydrogen gas at pressures of only a few millimeters, he determined the conditions of voltage, temperature, pressure, and distance between electrodes, which give maximum sensitiveness to the electric cell,—within the range of the experimental program followed. He found that his potassium-hydrogen cell was "about two hundred times more sensitive than the selenium cell." The astronomical applications of the cell were recognized as promising by KEMP when he wrote: "We hope to use these photo-electric cells for the measurement of the light from the fixed stars."

The selenium photometer as developed and applied to the study of variable stars by STEBBINS, in the past five years, had quite out-classed in accuracy all existing forms of photometers; but, early in the summer of 1913, STEBBINS wrote me from Europe that upon returning to Illinois he proposed to lay the selenium photometer on the shelf, at least for a time, and try an electric-cell photometer.

These preliminaries quite prepared me for ROSENBERG's paper, at the Hamburg meeting of the Astronomische Gesellschaft, in August, 1913, in which he presented some remarkable results obtained by MEYER and ROSENBERG with an electric-cell photometer attached to the 5-inch refractor of the Oesterberg Observatory, Tübingen, Germany, in measuring the light of stars between the fifth and sixth magnitudes: as well as for Director STRUVE's remarks on similar observations by GUTHNICK at the new observatory of Berlin University (nearly completed, at Neu-Babelsberg, near Potsdam).

By way of comment on ROSENBERG's paper, STEBBINS went to the blackboard and wrote down the following table, contrasting the work of MEYER and ROSENBERG's electric-cell photometer and his own selenium photometer. The numerical data may not be exactly correct, as printed below, for I write them down from memory; but they are essentially right.

Photometer.	Telescope.	Star of	Time to Make Observation.	Probable Error of One Determination.
Electric-cell	5-inch	5th mag.	2 min.	± 0.003 mag.
Selenium	12-inch	2nd mag.	60 min.	± 0.01 mag.

A few days following the Hamburg meeting I had the opportunity to see GUTHNICK's photometer attached to a small refractor, and to learn of some remarkable results obtained on certain interesting stars, but it is not for me to describe them.

If the electric-cell photometer, attached to small telescopes, can measure the light of a fifth-magnitude star, in a few minutes, with an accuracy of a few thousandths of a magnitude,—and this on the first trials of the instrument,—we are entering a new era in the study of the variable stars. The conspicuous difficulties may lie in the variable transparency of our atmosphere, or in the variable brightness of comparison stars. It may in fact be found that the star of constant brightness is the exception and not the rule. The electric-cell photometer may become as important a tool as the spectroscope and dry plate are.

August, 1913.

REVIEW.

By EDWIN B. FROST.

STELLAR MOTIONS, with special reference to motions determined by the spectrograph: The Silliman Lectures, delivered at Yale University by WILLIAM WALLACE CAMPBELL, Sc.D., LL.D., Director of the Lick Observatory, University of California. New Haven: Yale University Press, 1913. 8vo. Pp. 328, with numerous illustrations. Price, $4.00 net.

The value of endowed lectureships is fortunately not limited to the casual auditors or to the institutions in which they are given, however useful the stimulus of the presence of the guest from without may be to hearers and institutions. The lecturer himself is often a chief beneficiary, as a definite engagement may induce him to halt his work of observing long enough to make the necessary summaries and generalizations for his course of lectures. The general and special public gets its benefit when the lectures are printed and thus reach their widest circle of influence.

The temptation is strong indeed for a busy worker in a new and broadening field to continue to collect all the possible data in his laboratory with a view to furnishing an adequate basis for subsequent conclusions. The necessity of pausing to take account of stock and to draw preliminary inferences may, however, lead him to new inductions, more important than he may himself realize at the outset.

The officers of Yale University charged with providing for the course designated as "The Mrs. Hepsa Ely Silliman Memorial Lectures" were fortunate in choosing as lecturer Professor Campbell, Director of the Lick Observatory. Thus was insured an authoritative presentation of methods and results in one of the most important branches of modern astronomical research, for which most of the data was available on the spectrograms already obtained by the Lick Observatory in the effective campaign planned and executed by Campbell during the previous fifteen years.

The time was also particularly appropriate, as the feeling was developing among some astronomers that enough spectrographic data had already been collected to permit some reliable generalizations as to the motions of Sun and stars. Other investigators were taking up the subject, but none with data at all comparable with the rich material of observation in the possession of the Lick Observatory.

The lectures, eight in number, were delivered between January 24 and February 4, 1910. The preface is dated June 1, 1912, but the volume did not appear from the press until a full year later. This interval gave the author opportunity to refer in occasional footnotes to some of the interesting matters developing in the meantime. Each lecture constitutes a chapter in the book, averaging about forty pages in text.

The introductory chapter gives an excellent historical statement, especially referring to the development of the Doppler-

Fizeau principle of determining the linear velocity of celestial objects from the shifts of the lines in their spectra. It is interesting to note here that FIZEAU's lecture in 1848, in which the principle was first stated correctly, was not published until twenty-two years afterward, so little was its subsequent importance foreseen. A brief outline follows of the simple theory of spectroscopic measurements, and then is given a short discussion of the various types of stellar spectra.

The second lecture deals with the development of the photographic method, the requirements for accurate results, the proofs of the correctness of the observed motions, and the conditions other than those of motion which may affect the position of spectra lines. Proper emphasis is placed upon the immense advance made when photography was successfully applied in 1888 by VOGEL and SCHEINER at Potsdam to the spectroscopic measurements of motions in the line of sight. The next steps of progress were due to CAMPBELL in his design of the Mills spectrograph (1895-6) and his working out of methods of reduction of the spectrograms whereby the best stellar lines were utilized whether or not matched by comparison lines. The spark between iron electrodes was regularly used as source for the comparison spectrum (as originally suggested by VOGEL and so used by him for *Sirius*). Attention was paid to many small details of adjustment and observation, and a surprising and even unexpected accuracy was attained with the first "Mills spectrograph." This instrument certainly was fortunate in its prisms and other optical parts, for the definition has not been improved upon, for the brighter stars, by the later spectrographs designed at the Lick Observatory,—the instrument for Chile (1910) and the "New Mills" spectrograph (1902). The newer design, tending to eliminate flexure for longer exposures, extended the same accuracy (for a dispersion of three prisms) to the stars as faint as visual magnitude 5.0. In this chapter the student will be assisted by the quotations made from CAMPBELL's earlier papers, relative to his method of reduction of spectrograms, to the derivation of planetary velocities from the American Ephemeris by interpolation, and to the computation of the Earth's velocity in the direction of a star.

Chapter III treats of rotational velocities in the solar system and of the radial velocities for individual stars, the first topic including a short reference to the spectroscopic observation of the solar rotation and a fuller account of similar work on the planets. KEELER's classic paper in the first volume of the *Astrophysical Journal,* demonstrating the rotation of *Saturn's* rings, is quoted from at some length. Under the second topic are cited the observed values of separate plates of stars of different spectral types and of different magnitudes, chiefly from Lick results. The examples selected show remarkably good accordance. The effect of the solar motion is well exhibited to the general reader by the grouping of twenty-five velocities in the vicinity of the vernal equinox, of twenty-five near the autumnal equinox, and similarly for the region of the apex of the Sun's way near the constellations *Hercules* and *Lyra,* and for the region of the antapex. The stars' names were not given, consistently with the author's policy of not publishing individual values before the author's general studies upon them and generalizations from them could be completed with sufficient data.

Lecture IV deals in a clear and interesting manner with the solar motion as determined from stellar proper motions across the line of sight and with the systematic or "stream" motions of the stars. Of yet more interest is the following lecture, on the spectrographic determination of the solar motion, which was one of the main objects of the 10-years' campaign at Mount Hamilton and Santiago for radial velocities. A clear statement is given of the advantages of using the motions in the line of sight, but the author very justly adds: "However, the greatest value of radial velocities lies not in their advantage over proper motions, but in aiding proper motions to come into their own strategic worth." The simple procedure is given for deriving the right ascension and declination of the apex, and the solar velocity. Emphasis is properly placed on the difficult part of statistical investigations of this sort,—namely, the assignments of the proper weights for different stars and the possible rejection of stars in groups having parallel motions. This opens the way for a short story of the work (chiefly by LUDENDORFF) on the bright stars in *Ursa Major* and their [illegible] by our German friend is the [illegible] the description of the remarkable dis- [illegible] of the *Taurus* swarm. As [illegible] of the author's work we may [illegible] based on 280 stars [illegible] the apex [illegible] good but not perfect [illegible] from the proper motions [illegible] The two [illegible] quite different [illegible] types of spectra [illegible] between these absorption [illegible] the sixth lecture [illegible] the reader the [illegible] between radial velocity and spectral [illegible] were [illegible]

[illegible]

[illegible]

explanations suggested, that of a pressure effect in the extensive atmospheres of Class B stars appears to be by far the most probable one," an opinion probably now shared by most others concerned with this matter.

From this difference in the average velocities for SECCHI's first and second types; from the fact that the 280 radial velocities published by himself in 1901, chiefly of stars of types G, K and M, averaged 17.06^{km}, while twenty helium or B stars, observed elsewhere, averaged only 7^{km}; and from a preliminary tabulation of about sixty stars of class M, yielding about 17^{km} per second, CAMPBELL was able to state: "The progression of average velocity with advancing spectral type is clear and unmistakable."

A year after the delivery of the lectures fresh determinations of the solar motion were made, based upon nearly 1,200 stars, and fourteen solutions are given in Table XV, the different spectral types being treated separately. The constant K, or the apparent correction required for systematic error, is derived for all but one of the solutions, amounting to $+ 4^{km}$ (as already stated) for type B and for type M, to about $+ 1.0^{km}$ for A stars, to 0 for class F and G, but to about $+ 2^{km}$ for class K. The value of V_0, the Sun's speed, comes out about 20^{km} from the B stars, 17^{km} from the A stars, 15^{km} for the F and G stars and 21^{km} for the M stars; the author infers that "V_0 appears to be a function of the spectral class upon which it rests, at least as far as the brighter stars are concerned." This lecture concludes with a discussion of the average distances of the stars as derived from the relations of radial velocities and the proper motions, according to KAPTEYN's procedure, which is clearly stated. The radial velocities are also given in this chapter for eighty-eight stars with proper motions greater than $0''.50$, tabulated with reference to KAPTEYN's preferential vertex.

Chapter VII is devoted to the binary stars and naturally is chiefly occupied with spectroscopic binaries, from which no stellar spectroscopist can or would escape. The treatment is clear, and many interesting conclusions are drawn from this comparative study of these binaries and their orbits; the main points have been available to readers since the "Second Catalogue of Spectroscopic Binaries," by CAMPBELL appeared in 1910.

Chapter VIII treats of the variable stars, of course chiefly with respect to their radial velocities. Except for the eclipsing systems, there remains much to be explained regarding these bodies, but the known facts are brought out with the author's usual discrimination and judgment, and will hold the attention of even the untechnical reader.

While many of the topics, particularly of chapters VI and VIII, have been discussed by the author in the Lick Bulletins since the date of these lectures, the presentation given in this well-balanced volume will be found of the greatest value and convenience alike to those familiar with spectroscopic work and to those engaged in other astronomical or physical researches, as well as, and particularly, to college teachers of astronomy.

The typography of the book is excellent, and the proofs were evidently read with much care. Clearness would have been gained by the use of sub-heads in the chapters; but the changing running heads of the pages partly supply this deficiency. The numerous half-tones are fairly good, but they fail to do justice to the excellence of the originals, particularly in case of the stellar spectra. They should have been printed on a more suitable paper, as inserts; lighter paper could then have been used for the text, and the illustrations could then have been placed near the text describing them. They are without plate numbers and scattered at random through the book: in fact, one gets the impression that the printer failed to consult with the author on this matter. But these are only minor defects of a remarkably valuable book.

YERKES OBSERVATORY, November, 1913.

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1914.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter ..	Jan. 4,	$5^h\ 9^m$ A.M.	First Quarter ..	Feb. 3,	$2^h\ 33^m$ A.M.
Full Moon	" 11,	9 9 P.M.	Full Moon	" 10,	9 35 P.M.
Last Quarter ..	" 18,	4 30 P.M.	Last Quarter ..	" 17,	1 23 A.M.
New Moon	" 25,	10 34 P.M.	New Moon ...	" 24,	4 2 P.M.

There will be four eclipses during 1914, two of the Sun and two of the Moon.

The first of these is an annular eclipse of the Sun on February 24. No part of this will be visible from any part of the United States. The eclipse region lies almost wholly in the southern hemisphere, only a very small portion being north of the equator. The eclipse may be seen as a partial one from a part of New Zealand and a small portion of South America. These are the only places from which it may be seen even as partial, except a few small islands in the South Pacific.

The Earth is in perihelion and reaches its least distance from the Sun about noon of January 3d.

Mercury is a morning star on January 1, rising a little less than an hour before sunrise, and is therefore hardly visible to the naked eye at that time. It is rapidly approaching the Sun and passes superior conjunction on the night of January 24th-25th, becoming a morning star. It then moves away from the Sun and by the end of the first week in February it sets about an hour after sunset. It reaches its greatest east elongation, 18° 8′, on February 22d, and will then remain above the horizon about an hour and one half after sunset. This interval diminishes about a quarter of an hour by the end of the month, but for the last three weeks in February it may be seen low down near the western horizon in the evening twilight. The distance from the Sun is somewhat less than the average at time of greatest elongation, as this occurs about a day after perihelion passage. It is in conjunction with *Venus* on Jan-

[illegible] on January 22d, and with *Uranus* on [illegible]

[illegible] situated for observation during the two [illegible] of its proximity to the Sun. It is a [illegible] 1st, rising about forty minutes before [illegible] from the Sun diminishes rapidly and [illegible] conjunction on February 11th. It [illegible] evening star and will remain so until the [illegible] not be far enough away from the [illegible] until about the middle of March. [illegible] with *Mercury* on January 13th, with *Jupiter* [illegible] with *Uranus* on January 30th.

[illegible] position for observation since the an- [illegible] with the Sun in January [illegible] above the horizon [illegible] the evening [illegible] it will set about two hours before [illegible] constellation Gemini and on January 1st is [illegible] star [illegible] the stars is then westward retrograde. [illegible] until February 12th the distance [illegible] then begins and by [illegible] will have moved about 2° eastward [illegible] February its distance from the Earth will [illegible] of miles and its brightness [illegible] half. The present [illegible] as the least [illegible] of *Mars* [illegible] a little less than [illegible] greater than it was at the [illegible] nearly twenty [illegible] greater than [illegible] The next [illegible] unfavorable as the [illegible] The [illegible] present [illegible] about [illegible] 1911 and [illegible] that at [illegible] nearly one [illegible] greater than it [illegible] in 1915. The next favorable [illegible] until 1924. The [illegible] next years about [illegible] are unfavorable as is the case between the present one and the one next following. The interval will be only 766 days, while that between the oppositions of 1907 and 1909 was 811 days.

Jupiter is not in good position for observation. On January 1st it is an evening star, setting a little more than an hour after sunset, but its apparent distance from the Sun diminishes rapidly, and it comes to conjunction with the Sun on January 20th. It then becomes a morning star, and by the end of February it rises rather more than an hour before sunrise. It may therefore be seen for a few days at the beginning and end of the period.

Saturn passed opposition with the Sun early in December, and is therefore in good position for evening observation. It remains above the horizon until after 5 A. M. on January 1st, and until after 1 A. M. on February 28th. It is in the constellation *Taurus* north and east of the first-magnitude star *Aldebaran*. It moves westward about 2° until February 11th and then moves slowly eastward. As seen in the telescope the ratio of minor to major axis of the rings is about 44 per cent, nearly the maximum.

Uranus is in bad position for observation, as it comes to conjunction with the Sun on January 27th, being an evening star until that date and a morning star afterward, but too near the Sun for naked-eye observation throughout the two months.

Neptune is in opposition to the Sun on January 17th, and is then in the range of vision throughout the entire night. It is on the border-line between the constellations *Gemini* and *Cancer*.

(SEVENTY-EIGHTH)[1] AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur A. SCHAUMASSE, of Nice, France, for the discovery of an unexpected comet on May 6, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

(SEVENTY-NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Rev. J. H. METCALF, of Taunton, Massachusetts, for the discovery of an unexpected comet on September 1, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

(EIGHTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur G. NEUJMIN, of Simeis, Russia, for the discovery of an unexpected comet on September 3, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

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[1] The three Comet-Medal awards made on November 30, 1912, and announced in these *Publications* (Volume XXIV, page 268), were inadvertently given numbers too small by one. They should be numbered respectively (Seventy-fifth), (Seventy-sixth), and (Seventy-seventh).

NOTES FROM PACIFIC COAST OBSERVATORIES.

NOTE ON THE DETERMINATION OF RADIAL VELOCITIES OF NEBULÆ.

For several years it has been planned, as soon as opportunities should come, to measure the radial velocities of all so-called gaseous nebulæ whose intrinsic brightnesses are sufficient to record their spectra in exposures of reasonable lengths.

Observations of the southern nebulæ were begun in 1911 by Messrs. MOORE and SANFORD of the D. O. Mills Expedition, and they have secured measurable spectrograms of eight nebulæ not hitherto observed for this purpose. Similar observations were begun at Mount Hamilton in the early summer of 1913 by Mr. MERRILL, Fellow in the Lick Observatory, and continued until September, when he assumed new duties as a member of the staff of the Detroit Observatory. Since September the observations have been continued chiefly by Messrs. PADDOCK and HAYNES. Confirmatory spectrograms have been secured for nine of the thirteen planetary nebulæ observed in 1890-91 by KEELER, and for fifteen additional northern nebulæ.

Some interesting results of the recent northern observations are described in the following note. W. W. CAMPBELL.

November, 1913.

A NEBULA WITH LARGE RADIAL VELOCITY.

The velocities of approach or recession recently determined here for fifteen nebulæ are in accord with KEELER's results for thirteen other (planetary) nebulæ, viz.: the average velocity is high.

The tenth-magniture planetary nebula, No. 4846 in the Second Index of Dreyer's New General Catalogue (R. A. = 19^h $11^m.0$, Dec. = — 19° 14′), has an abnormally high velocity. The mean of the observed velocities obtained from three photographs is approximately 150^{km} per second, recession, with reference to the Sun; or, correcting for the effect of the solar motion, 165^{km} per second with reference to the stellar system.

The results for the other fourteen nebulæ vary from about 60^{km} approach per second to about 60^{km} recession, with reference to the stellar system.

W. W. CAMPBELL,
E. S. HAYNES.

A SOUTHERN NEBULA WITH LARGE RADIAL VELOCITY.

Two spectrograms of the planetary nebula N. G. C. 5873 ($\alpha = 15^h 6^m.3$; $\delta = -37° 43'$) were obtained with the one-prism spectrograph at the D. O. Mills Observatory, Santiago, Chile, in March, 1913. The mean of the measures of these two plates by MISS HOBE, Mrs. MOORE, and Mr. MOORE give for the radial velocity of the nebula with reference to the Sun — 136^{km} per second. Its velocity in the line of sight referred to the stellar system is therefore — 133^{km} per second. The velocity determinations depends upon measures of the nebular lines λλ 4340, 4686, 4861, 4959, and 5007.

J. H. MOORE.

A STAR WITH A REMARKABLE RADIAL VELOCITY.

In the course of our observations of the radial velocities of the fainter stars with measured parallaxes, we have found the star Lalande 1966 (α 1900 = $1^h 3^m.3$) to have an extraordinarily high velocity. Three spectrograms of the star give the following values:—

1913 Sept.	17	-326^{km}
Oct.	10	325
Oct.	17	323
		-325

The spectral type of the star is F3. The parallax of the star as found by the Yale observers is + 0″.08. If we assume this value and the proper motion given by KAPTEYN, we find the motion in space to be 320^{km} per second, directed toward the apex $\alpha = 188°$, $\delta = -59°$.

W. S. ADAMS,
A. KOHLSCHÜTTER.

SOME RECENT OBSERVATIONS OF NOVA GEMINORUM 2.

Occasional photographs of the spectrum of *Nova Geminorum* taken during the year have shown some interesting changes in the relative intensities of certain of the bright bands. The most important of these is the Rydberg hydrogen line at λ 4687. As early as May, 1912, this line was fairly bright and well defined. During that summer, however, it must have decreased greatly in brightness, as photographs taken in August and September showed mere traces of it. In November, however, it became bright again and ever since that time it has remained a prominent feature of the spectrum, gradually gaining in intensity. The two nebular bands at about λ 4612 and λ 4641 have also fluctuated widely. In April, 1913, the λ 4641 band was very strong and the λ 4612 band very weak, while in October the λ 4612 band was considerably the stronger of the two. The regular hydrogen bands have shown a steady decrease in intensity during the observations and the principal nebular bands have shown an increase.

The most recent photograph, taken on October 12th, shows the nebular bands at λ 5007 and λ 4364 as the strongest features of the spectrum and λ 4959, λ 4687, and λ 4612 of about equal intensity, the first being slightly the strongest. The hydrogen lines $H\delta$, $H\gamma$ and $H\beta$ are all comparatively faint. A band near λ 4520 is nearly as bright as $H\gamma$. These bands, with the nebular band at about λ 4641, which is somewhat fainter than λ 4687, are all of the conspicuous features of the spectrum. A very faint continuous spectrum is visible.

All of the bright bands are from 20 to 30 Ångstrom units wide and show absorption lines passing through their centers. This has been a characteristic feature of the Nova spectrum since early in its history.

W. S. ADAMS.
A. KOHLSCHÜTTER.

NEW EQUIPMENT FOR THE CHABOT OBSERVATORY.

On account of the constant increase of electric lights, and the encroachment of high buildings, it has become necessary to move the Chabot Observatory. The matter was urged before the Oakland Board of Education, and it unanimously agreed to move the observatory out of the business section to a favorable locality, not yet decided upon; and, also, upon my advice, authorized the purchase of a 20-inch refractor for the new observatory.

The funds left by Mr. Chabot over twenty-five years ago, "to enlarge and add to the equipment of the observatory," is available for removal and new building, while the new telescope will be purchased by the School Department.

CHARLES BURCKHALTER.

OAKLAND, CAL., November, 1913.

RATES OF THE STANDARD CLOCKS AT THE LICK OBSERVATORY.

There are four clocks in use, keeping sidereal time. The Riefler clock case was closed in April, following the rating of the clock in the new case. Its mean rate for about five months has been $-0^{s}.25$ at temperature 55° Fahrenheit and pressure 0.040 m. There are no means of keeping the temperature constant within the clock case, but the location of the clock in the basement of the meridian-circle house, and the protection of double doors to the clock room, result in slow periodic fluctuation only. The computed change of rate for the past five months is $-0^{s}.01$ per degree Fahrenheit and the application of this change reduces the average residual, for periods of about one week, from $\pm 0^{s}.08$ to $\pm 0^{s}.06$. While the case has been practically air-tight, the changes of temperature produce corresponding fluctuations in the pressure amounting to -0.0014 m. per degree Fahrenheit. The range of temperature in five months has been twenty degrees, while the average weekly change is about three degrees.

The Dent clock has also been rated, from the corrections by direct observations of the stars, simultaneously with those for the Riefler rate. Its rate was changed the first of August, by the addition of a small weight placed on the pendulum shelf. The present rate is $+0^{s}.91$ at temperature 70° Fahrenheit, and the change of rate, for the last five months, is $+0^{s}.03$ per degree, corresponding well to that determined from the rating of many previous years. The application of this change reduces the average residual for the past five months, in weekly periods, from $\pm 0^{s}.11$ to $\pm 0^{s}.06$. The temperature for this clock, in the inner room of the clock room, averages 8° above that of the Riefler, with about the same average weekly changes, but with smaller daily fluctuations.

For comparing the performance of these clocks, the rates of the two Höhwu clocks, No. 3 and No. 8, for the past two months are given below, with their residuals, and those of the Riefler and Dent, for the same period:—

	Rate.	v	Temperature Correction.
Riefler	$-0^s.34$	$\pm 0^s.04$	$\pm 0^s.03$
Dent.	$+0.91$	± 0.11	± 0.07
Höhwu, No. 3	$+0.13$	± 0.08	. . . . . .
Höhwu, No. 8	$+0.57$	± 0.09	. . . . . .

The rates of the two Höhwu clocks do not show any dependence upon the temperature.

The two mean time clocks, Frodsham and Howard, are rated to Pacific Standard time, and the rates are changed as often as necessary, by the use of small weights, to keep the errors within a small fraction of a second. R. H. Tucker.

September 24, 1913.

Note on Comet *c* 1913 (Zinner-Giacobini).

A telegram received on October 24th announced the discovery of a comet by Zinner and gave an observation of it on October 23d by Hartwig at Bamberg. On the basis of this observation and two on October 24th and 25th by Dr. Aitken of the Lick Observatory, parabolic elements and an ephemeris were computed.

On October 27th a telegram was received giving the elements computed at Kiel and also stating the suspected identity of this comet with Comet 1900 III. A conditioned solution of the orbit on the basis of the same three observations was immediately undertaken, the assumed period being that derived by Kreutz for Comet 1900 III. The results of this conditioned solution established the identity of the two comets. Both the parabolic and elliptic elements and the ephemerides have been published in *Lick Observatory Bulletin,* No. 245.

The period of the comet is 6.464 years, this being the second return since its discovery in 1900 by Giacobini. It was not rediscovered at the time of its first return. When discovered this year it was in the constellation *Scutum*. Its motion southward and eastward has since taken it into *Sagittarius* and *Capricornus*. Its nearest approach to the Sun was on November 2nd, when it was at a distance of about 91,000,000 miles.

ANNA R. KIDDER.

BERKELEY ASTRONOMICAL DEPARTMENT.

NOTE ON COMET *c* 1913 (NEUJMIN).

According to the orbit published in *Lick Observatory Bulletin*, No. 245, this comet is moving in an ellipse with a period of 17.83 years. The orbit is inclined 15° to the plane of the ecliptic. It is a very interesting fact that the comet's path lies for a short distance very near to the orbit of the planet *Mars*. For a distance of about 40,000,000 miles the two orbits are almost parallel, the comet's path being but 570,000 miles further from the Sun than that of *Mars*. At the present perihelion passage, which occurred on August 16th of this year, *Mars* was considerably ahead of the comet, so that they did not get closer than 100,000,000 miles. The comet is now in the Square of *Pegasus*, but it is too faint to be seen except with the largest telescopes. On November 4th, Professor BARNARD of Yerkes Observatory described the comet as seen in the 40-inch refractor as showing no trace of nebulosity and looking exactly like a star of 13½ magnitude. For a detailed account of the discovery of the comet and its appearance, see the note by Dr. AITKEN on September 23, 1913, printed in these *Publications* for October, 1913.

SETH B. NICHOLSON.

BERKELEY ASTRONOMICAL DEPARTMENT.

NOTE ON COMET *d* 1913 (DELAVAN-WESTPHAL).

The fourth comet of the year was discovered by DELAVAN at the La Plata Observatory, Argentina, on September 26th. At that time it was in the constellation of *Aquarius* and was moving westward and northward.

In *Astronomische Nachrichten* 4619, Mr. ADOLF HNATEK gives search ephemerides for the current year corresponding to different assumptions for the period of WESTPHAL'S periodic comet. Interpolation from these, on the basis of the observations of September 26th and 27th of DELAVAN'S comet by HUSSEY and AITKEN respectively, yielded the period 61.121 years, thus confirming the identity of the new comet with WESTPHAL'S comet of 1852.

Observations of September 27th and 30th and October 4th, by Dr. AITKEN of the Lick Observatory, formed the basis of a differential correction of HNATEK'S elements, conditioned by the assumption of a period of 61.121 years. In this connection it should be stated that Professor LEUSCHNER'S formulæ are so arranged that it is a simple matter to compute an orbit on the basis of *any* adopted period. The elements of the orbit and an ephemeris are given in *Lick Observatory Bulletin*, No. 244.

The comet is moving in a plane inclined 44° to the plane of the ecliptic. Its nearest approach to the Sun will be on November 26th, at a distance of 117,000,000 miles. It has been receding from the Earth since discovery. Maximum brightness was reached early in October, so that the comet will not become visible to the naked eye, as in 1852.

The following comment by Professor BARNARD of the Yerkes Observatory, just received in a letter from him to Professor LEUSCHNER, may be of interest: "WESTPHAL'S comet is simply gone to pieces. It is a vague, somewhat elongated mass of feeble light $2' \pm$ in diameter. A setting for position could not be made closer than $1'$. It is most extraordinary. There is no condensation and no form to it. It is faint."

SOPHIA H. LEVY.

BERKELEY ASTRONOMICAL DEPARTMENT,
November 10, 1913.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report and discuss the more important articles appearing in the journals of astronomy, and to abstract new books on astronomical subjects, or subjects of current and special interest in the Observatory's work. It has been suggested that abstracts of these reviews would be of interest to the readers of these *Publications*, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict unasked criticisms, favorable or unfavorable, to a minimum.

Radial Velocities and the Objective Prism.

Stellar spectroscopy has two main problems, the interpretation of the qualitative and the quantitative results obtainable from spectrographic photographs. From the former flow, or may be derived in the future, classification of stellar spectra, and data on physical conditions and transformations of the stars. From the latter proceed radial velocities, the Sun's velocity through space, the relative amounts of velocity pertaining to the different spectral classes of stars, confirmation of star-streaming and associated data, and orbits of spectroscopic binaries. The qualitative results are more easily obtainable than the quantitative, since much can be derived from objective prism photographs. Quantitative results depend upon comparison spectra, which have thus far been satisfactorily obtained only with slit spectroscopes. The slit spectroscope is excessively inefficient and requires very much longer exposures than the objective prism apparatus. Three-prism spectroscopes are impracticable beyond the fifth magnitude and two prisms beyond the seventh, while one prism does not give accurate velocities. The quantitative problem therefore needs the development of new methods for stars beyond the fifth magnitude.

A discussion of this problem by Dr. Schlesinger has recently appeared in the *Proceedings of the American Philosophical Society*, **3**, 1913, and the following points are taken from the article.

Extension of radial velocity work to stars of sixth, seventh, eighth, and ninth magnitudes is much desired. Larger telescopes with slit spectrographs will gain very little, since 12-inch telescopes have been able to do certain work almost as efficiently as the largest telescopes. The photographic plate in a slit spectrograph receives only one or two per cent of the light that falls upon the objective of the telescope, while with the objective prism, the plate may receive as much as 25 per cent. Furthermore the slit spectrograph secures only one spectrum at a time, while the objective prism may secure several on the same plate. But the lack of means of placing satisfactory comparison spectra upon objective-prism plates prevents the determination of velocities from such plates. Several methods of securing objective-prism spectra in such a way as to determine velocity have been suggested, but none developed. They are briefly explained as follows:—

A quarter century ago Pickering suggested, in connection with experimental work for the Draper Memorial, that radial velocities might be determined if some absorptive medium which would produce one or more narrow and sharp lines could be placed in the objective-prism telescope. He did not find a satisfactory absorbing medium, but R. W. Wood has since proposed neodymium chloride, which gives a fairly sharp and narrow line at wave-length 4272. Experiments are being made with it, but its accuracy is not more than that represented by a probable error of ten kilometers. The method is applicable only to stars of early type, since with solar and later types the neodymium lines would be involved with the stellar lines.

Pickering has also suggested the method of reversing the objective prism, which is set with its edge parallel to the equator. Two adjacent stars would be selected for the determination of their relative velocity, and would be photographed in both positions of the prism. The result would be two pairs of spectra, one with violet ends north and one with violet ends south. A difference of radial velocity in these stars would produce a difference of distance between identical lines in the two spectra such that half the difference of the measured distances would be a measure of the relative radial velocity. In other words, the K line of a star approaching the Sun would be shifted toward the violet,—that is, first toward the north, then toward the south an amount more or less than the K line in the other spectrum according as the velocity is more or less than that of the other star. The reversing of the prism could be effected by reversing the telescope about the polar axis and one of the plates could be exposed with film behind the glass so that in measurement the two plates could be placed film to film for differential measurement. STEWART has suggested the use of two objectives with oppositely placed prisms adjusted to place the direct and the reversed spectra side by side on the same plate. COMSTOCK suggested that the two prisms be placed over a single objective, with their refracting edges meeting on a diameter of the objective. SCHLESINGER has suggested two independent objective prism cameras under constant temperature control. There are serious difficulties to be dealt with; for instance, in case of independent exposures, differential refraction, and dissimilar guiding; also the distortion of the field due to the prism or the prismatic astigmatism which curves the spectra in one direction and unequally lengthens or shortens them in the other. These distortions are least in COMSTOCK's design and practically absent in STEWART's design with the spectra at the centers of prisms, objectives, and plate. Patience, perseverance, and skill would probably overcome the difficulties.

A further method is made possible by the following circumstance: In prismatic spectra velocity displacements are greater in the violet than in the red region. The spectra are therefore shortened for receding stars and lengthened for approaching stars. The possibility of determining velocities from the change of length of spectrum caused by velocity occurred also to PICKERING, who remarks, on page xxi of volume **26**, of the *Annals of Harvard College Observatory:* "The change in length of the spectrum due to the motion of the star would only amount to about one sixth" of the displacement of the lines due to motion, "and could not readily be distinguished from a variation in temperature of the prism." This suggestion, however, may now lead to valuable results because of the recent developments in the use of photographic plates. Since the staining of plates with certain dyes has been found to render them sensitive to yellow and red wave-lengths, a greater length of spectrum and therefore a greater amount of change of length of spectrum are available. Formerly only the violet from λ 3800 to λ 4800 could be photographed; but now the spectrum from λ 3800 to λ 6500 can be obtained. The ordinary objective, however, does not bring to focus all of this region. An objective or correcting lens could be made to bring to the same focus the region round about λ 4000 and that round about λ 6000. A great difficulty in objective-prism work is the displacements caused by change of temperature, but a constant temperature case like that used with slit spectrographs could be applied to the entire objective-prism instrument. The prism would have to be calibrated by stars whose velocities have been determined with slit spectrographs. The spectrum of a star of known velocity could be placed beside the spectrum of the star of unknown velocity. The difference of length of the two spectra could then be measured and the corresponding amount of velocity added to the known velocity.

It might eventually be desired to increase the light-gathering power of the apparatus without increasing the size of the objective prism. This might be accomplished by replacing the secondary of a Cassegrain reflector by a convex paraboloid or by placing a diverging lens near the focus of a refractor, in each case to obtain a condensed beam of parallel light of the size of the objective-prism camera.

The prospect of obtaining radial velocities by means of the objective prism seems good enough to warrant a trial of all three of the methods above mentioned. The use of the absorbing medium would probably lead to immediate results, but with only a moderate degree of precision. The method depending upon the length of spectrum might be developed to give accurate results.

G. F. PADDOCK.

November, 1913.

DISCUSSION OF THE REVISED HARVARD PHOTOMETRY.

Number IV of Volume LXIV of the *Annals of the Harvard College Observatory* is devoted to a thorough discussion of the errors contained in the numerous photometric catalogs upon which the Revised Harvard Photometry (H. A., **50**) is based.

The method adopted was that of grouping the stars in the R. H. P. according to their position in the sky, their magnitude and their spectrum. The sky was divided in forty-eight sections exactly equal in area, for position; the stars were to be divided into six groups according to magnitude, and also into six groups according to their spectra. The 9,110 stars were thus divided into a possible 1,728 groups. "Some of these groups do not contain any stars. The number of stars in each group and the algebraic mean of the sixteen residuals given in the Revised Harvard Photometry were next taken."

The major portion of the present publication is composed of condensed tables exhibiting these residuals and the conclusions that are to be drawn from them as to the accuracy of the various photometric catalogs. The conclusion is:—

> "The observations contained in the various meridian photometer catalogues, although extending over a period of twenty-seven years, and made with different instruments, by different observers, and in different places, agree closely as regards scale, the differences amounting to only a few hundredths of a magnitude. . . . The agreement as regards color is also good, for nearly all the catalogues."

But the data in these tables can also be used to study the distribution of the stars of different classes of spectra, and it is this study that yields the most interesting and important conclusion contained in the paper. It may best be stated in Professor PICKERING's own words:—

> "The theoretical value of the coefficient, *a*, which connects the logarithm of the number of stars with the magnitude, is 0.60. The observed value of this constant from all the bright stars is 0.51, from which the existence of an absorbing medium in space has been inferred. Grouping the stars according to their spectra, we find that for stars of Classes A to F, from the fourth to the sixth magnitude, the coefficient is very nearly 0.60. Great doubt is thus thrown on the existence of an absorbing medium. The coefficient far stars of Classes G, K, and M is about 0.51, while for stars of Class B it is much smaller, 0.42, indicating that there are few faint stars of this class. Except in the case of Class B, there is no distinct evidence that there are more stars on one side of the Sun than on the other."

R. G. AITKEN.

October, 1913.

DIE VERÄNDERLICHEN STERNE: ERSTER BAND; GESCHICHTLICH-TECHNISCHER TEIL. VON JOHANN GEORG HAGEN, S. J. ERSTE LIEFERUNG: DIE AUSRÜSTUNG DES BEOBACHTERS.[1]

Father HAGEN has evidently undertaken the preparation of a very complete work on the variable stars, for the present book—in xv + 152 quarto pages, dealing with the Observer's Equipment—forms only Part I, Volume I. The remaining parts of this volume will be three, dealing, respectively, with the Methods of Observing, the Reduction of the Observations, and the Elements of Light Variation. This will complete the discussion of the historical and technical phases of the subject. The second volume will then take up the discussion of the theories, both mathematical and physical, to account for the observed phenomena, which at present are attracting ever increasing attention.

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[1] Freiburg im Breisgau. 1913. 4to. xv + 152 pp.

After a brief preface, in which the author acknowledges his indebtedness to Professor MÜLLER of Potsdam, who read the proof sheets, a careful bibliography, covering seven pages, is given. In this, only separately printed books, publications of observations and transactions of academies are included. Reference is made to articles in scientific journals, only "when on account of their age or contents they have special value,"—as, for example, the catalogs of variable stars, and the meager notes on star colors.

The text proper consists of an introduction, treating (a) of the beginning and the significance of the theory of the variable stars and (b) of the various methods of observing, and of five chapters, discussing, in order, the history and literature of this new branch of science, the classification and distribution of the variables, the catalogs, nomenclature and alphabetic designations, the instruments, star charts and ephemerides, and, finally, the observing program.

The method of treatment is the historical one, copious references being made to the original papers. As all of the references have been carefully verified, the volume may be regarded, as the author says, as a source book. While the first chapter gives to ARGELANDER the credit of being the founder of this branch of astronomy, and makes special mention of his immediate colleagues and pupils, it also gives a fair account of the independent development of the subject outside of Germany, and particularly in England under POGSON and KNOTT and BAXENDALL, and brings the history down to date with an account of the increased activity of variable-star observers during the past ten years.

In the second part of this chapter emphasis is placed upon the necessity of publishing the *original data* of the observations and not merely the results. Then follow full descriptions of the various methods that have been adopted in reducing and publishing observations, reference being made to numerous publications as examples.

The classification of variable stars is very fully treated in the second chapter. New stars, missing stars, stars that have been suspected of momentary variations as well as those supposed to vary in periods of many years, are first discussed. Next follows a section on the non-periodic variables, with a discussion of what constitutes "regularity" or "irregularity" in a variable star, then a section on the periodic variables.

A full account is given of all the proposed classifications of variable stars from PIGOTT's, in 1786, to those adopted at Harvard and in the *Viertel-jahrs-schraft* der Astronomischen Gesellschaft, with reference, also, to recent proposed classifications on a physical basis, rather than on the apparent character of the light curve. The chapter closes with a section devoted to the various published estimates of the number of variable stars, and the investigations of their distribution, as a whole, and of the various classes, with respect to the Milky Way.

This somewhat detailed account of the contents of the first two chapters will sufficiently illustrate how thoroughly the author has treated every phase of his subject.

The book will be found helpful to students and observers, both by reason of its full references to original memoirs and by reason of the author's many valuable suggestions.

The general rules laid down in the last chapter for the formation of an observing program will be found especially helpful. To form a program that is adapted to the observer's equipment, and that, when carried out, will contribute definitely to the progress of astronomy, is, as the author says, of the greatest importance. His warning as to the difficulty experienced in carrying a well-conceived program to a definite conclusion is also worth heeding. The present writer, however, regrets that the author considered it necessary to quote examples of failures in this respect.

R. G. AITKEN.

October, 1913.

Radial Motions in Sun-Spots[1].

That the Fraunhofer lines in the outer edges of the penumbræ of sun-spots are systematically displaced was announced by Mr. Evershed in 1909, and the hypothesis was advanced that these displacements are due to the radial motion outward and tangential to the solar surfaces of the gases of the reversing layer.

The present paper gives the results of an investigation made with the spectrograph of the 60-foot tower equipment on Mount Wilson by Mr. St. John, with a view to throwing additional light upon this interesting phenomenon. For favorable observations of the displacements, the sun-spot should be located neither near the limb nor near the central meridian, and the slit of the spectrograph should be placed along the line joining the center of the spot and that of the solar disc for observing the maximum displacements.

When the spectra of the outer edges of the penumbra, directed respectively toward the limb and center of the Sun's disc are photographed side by side on the same plate, the relative displacement of the lines in the two spectra are quite marked and are such as to give, in general, a greater wave-length for the lines of the reversing layer in the edge of the penumbra on the limb side. The displacements were studied for some five hundred lines distributed in the violet, blue and yellow regions, and so chosen as to include a wide range in intensity of lines. In all, the lines given by about twenty-six elements were investigated.

The displacements are found to vary systematically with the intensity of the lines in amount and sign, and further are proportional to the wave-length for lines of the same intensity. This last fact seems to indicate clearly that the observed change in wave-length is due to the Doppler effect. If the displacements, reduced to a common wave-length, are arranged according to the intensities of the lines of any one element (iron, for example, for which he studied some two hundred lines), a remarkable series is found in which the displacements decrease systematically with increase of intensity of the lines. On the hypothesis that the displacements are due to radial velocity, they indicate an outflow of matter from spots tangential to the Sun's surface with a velocity of 1.02^{km} per second for lines of intensity 00 and a velocity of 0.12^{km} per second for lines of intensity 10. For lines of greater intensity the displacements reduce to zero and for the strong lines of intensity 20 to 40, as for those of sodium, magnesium, hydrogen and calcium, the displacements change sign, indicating an inflow of vapor of high levels into the spot, with velocities ranging from 0.6^{km} per second to 1.89^{km} per second.

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[1] *The Astrophysical Journal*, **37**, 322, 1913; *The Observatory*, **36**, 395, 1913.

In order to explain the observed connection existing between radial velocity and intensity of the lines, it is assumed as a working hypothesis "that these systematically varying displacements or velocities are due to the differences of level at which the solar lines originate" and that on the whole the weaker lines originate lower in the solar atmosphere than stronger lines. On this assumption the distribution of velocities in a vertical section of a sun-spot shows the maximum velocity of inflow at the higher levels, which decreases to zero as we descend, changes sign and reaches maximum velocity of outflow at the lowest level in which the faintest lines are assumed to have their origin. The author points out that this apparent circulation cannot be a true vortex, as the matter flowing in at the higher level is neither the same in quality nor in quantity as the matter flowing out at the lower level. The actual vortex, he believes to be much lower than the phenomenon under observation, and that the outflow into the reversing layer is the upper portion of the low-lying vortex, while the inflow from the chromosphere is merely a secondary or superficial effect of this.

While the line displacements vary regularly with the intensity of the lines of any one element, they are not equal for the lines of the same intensity of different elements. For example, the lines of titanium show a smaller positive velocity than the lines of iron of the same intensity. This is interpreted on the above hypothesis as indicating that the titanium producing a line of any given intensity is at a higher level than that in which the iron line of the same intensity originates. The series of iron lines arranged according to intensities and their corresponding displacements forms, according to the above interpretation, a sounding level for indicating the vertical distribution of the elements in the solar atmosphere. The resulting distribution found by making this comparison of the lines of different elements with those of the iron series is one in which the elements of high atomic weights occur at the low levels, while the lighter elements are found at all levels.

The author states that the interpretation of the phenomena given above "is confirmed by flash spectrum observations, and is in harmony with a wide range of solar observations in which indications of effects due to differences of level have been obtained."

J. H. MOORE.

PHOTOGRAPHS OF COMET *a* 1910.

Lowell Observatory Bulletin, No. 57, contains a number of excellent photographs of Comet *a* 1910, with a discussion of the plates by Mr. C. O. LAMPLAND. The usual formulæ for calculating the true position of points in the tail are collected, and modifications are derived for obtaining these values in rectangular co-ordinates as well. Of particular interest are the photographs showing the striated form of tail, of which DONATI's comet has hitherto been almost the only example. The theory of these striæ is that a cloud of matter containing particles of slightly different size is ejected from the nucleus. Owing to the variation in size of the particles, the light action and the repulsive effect will differ, and will have the effect of drawing out the original cloud of matter into a long line. POKROWSKY has calculated the values of the repulsive force for the striæ in this comet from a photograph made by SYKORA *at* Taschkent on January 27, 1910, and has found that the repulsive action varied from $\mu = -1$ to $\mu = +0.3$.

H. D. CURTIS.

PROPER MOTIONS OF FAINT STARS.

This important paper by Professor COMSTOCK, which has just appeared in No. 655 of the *Astronomical Journal,* is certain to give rise to considerable discussion, and cannot fail to have influence on current theories of the structure of our stellar universe. The opinion most generally accepted has been that the fainter stars, because of their presumably much greater average distance from us, have proper motions in general vanishingly small. It is true that the spectrographic results of the past decade, for stars extending roughly down to the sixth magnitude, have shown that, up to this point at least, the brighter and the fainter stars are much more intimately intermingled than had been hitherto supposed. But for still fainter stars the opinion has been pretty generally held that they are, relatively to the brighter stars, almost absolutely stationary as far as proper motions are concerned. This has been accepted without question and has formed the basis for a number of lines of stellar research, as, for example, the determination of stellar parallaxes, though the fact that nearly twenty-five per cent of the best modern determinations of parallax give negative parallaxes is rather disquieting.

The paper is a continuation of the work inaugurated by Professor Comstock in Volume XII of the *Publications of the Washburn Observatory*, and he has now investigated the proper motions of 513 stars fainter than the eighth magnitude; of these 300 are believed to show proper motion. The accuracy of the results is discussed at length, and from the proper motions of these fainter stars a value is found for the apex of the Sun's way and for vertices of preferential drift. To quote some of the conclusions reached:—

Out of five hundred stars included between the seventh and thirteenth magnitudes, that have been observed for their proper motion, approximately seventy-five per cent yield sensible proper motions.

These proper motions confirm and extend from the brighter stars at least to the twelfth magnitude the relation that, in the mean, the amount of proper motion is inversely proportional to stellar magnitude. The relation is expressed by $\mu m = 35''$, where m is the magnitude and μ the proper motion per century.

The linear velocity of stellar motions is substantially independent of stellar magnitude.

The faint stars and bright stars are parts of one and the same stellar system and are in great measure intermingled, the faint stars being less remote than has been inferred from photometric considerations.

H. D. Curtis.

THE PLANE GRATING FOR STELLAR SPECTROSCOPY.

Under the above title in the *Astrophysical Journal* for June, 1913, Mr. J. S. PLASKETT gives some interesting results of a comparison of the relative intensities of spectra obtained with spectrographs in which the dispersing piece is a plane grating, a silvered half-prism, one prism or three prisms.

A plane grating of 15,000 lines to the inch and estimated to diffract about 30 per cent of the incident light into one first order was mounted in a spectrograph of the usual form for comparison with the one-prism instrument of the same linear dispersion at Hγ. A second spectrograph was constructed, of the Littrow type, in which either the grating or a silvered half-prism could be used, and which had a linear dispersion at Hγ equal to that of the Dominion three-prism.

A comparison of the relative intensities of the spectra photographed with these several instruments was obtained in the usual way from successive exposures of different lengths on the same celestial objects. The general results of this comparison are briefly the following:—

First, the marked superiority of grating over prismatic spectra in the uniformity of intensity from Hβ to λ 3850.

Second, that in relative intensity of the spectra the three-prism has the advantage over the grating from Hβ to λ 4300, while for the region to the violet of λ 4300 the advantage is with the grating.

Third, that single or half-prism spectra are more intense than those of the grating from Hβ to the K line.

The lack of uniformity in intensity of prism spectra and their inferiority in intensity in the violet region as compared with grating spectra is due, as is well known, to the rapid increase in dispersion and absorption of a glass prism in the region of short wave-lengths.

A grating may therefore be used to advantage in stellar spectrographs for studies in the region of the K line and farther to the violet, or where uniformity of intensity or dispersion is required. From the results here given, it appears that if a grating were ruled giving twice the intensity of the one used in the present experiments, it would be superior to single-prism dispersion for most work.

J. H. MOORE.

BOND ZONES OF FAINT EQUATORIAL STARS.

The 15-inch east equatorial of the Harvard College Observatory was for many years the most powerful telescope in this country and had but one equal in Europe—the 15-inch equatorial at Pulkowa. One of the large pieces of work accomplished with this instrument in the years 1852 to 1860 was the observation of the faint stars in the zone from the equator to 1° north declination. The results were published in *Harvard Annals*, I Pt. II, II Pt. II, and VI, and are now brought together in a single catalog on a homogeneous system. The work was carried out by Miss MARGARET HARWOOD, assisted by Miss MARY O'REILLY, under the direction of Professor PICKERING, and the catalog forms Volume LXXV, Part I, of the *Annals*.

The Nicolajew catalog of the Astronomische Gesellschaft contains the positions of 1,756 stars that are also included in the Bond Zones. These furnished the data necessary to reduce the Bond places to the Nicolajew system, an ingenious graphical method being employed to find the corrections. As, in general, each zone was observed twice, usually on consecutive nights, the data were also available for detecting errors of various kinds, and for estimating the probable error of a star-place. This is found to be, for a star observed in two zones, ± $0^s.06$ in right ascension and ± $0''.6$ in declination.

The average magnitude of the stars is below 11, and stars as faint as 13 and 13.5 are to be found in the catalog. The chief value of the catalog is that it affords "almost the only material now available for determining from visual observations the proper motions of the faint stars."

R. G. AITKEN.

October, 1913.

A CATALOGUE OF 16,300 STARS OBSERVED WITH THE 12-INCH MERIDIAN PHOTOMETER—E. C. PICKERING.

The record of the extensive photometric observations made at the Harvard College Observatory is continued in Volume LXXIV of the *Annals*, which contains the results of Professor PICKERING's own measures with the 12-inch meridian photometer on stars other than those in the Durchmusterung Zones published in *Harvard Annals*, **70**.

The stars may be divided into classes showing the reasons for their selection:—sequences for variable stars, stars from the Bond Zones (referred to in another note in this number of the *Publications*), stars from KAPTEYN's Selected Areas, comparison stars for Halley's Comet, for *Eros* and other asteroids, etc,—in all twenty-five different classes of stars. The great majority are faint, ranging from magnitude 9.0 to 13.5.

The volume, in its arrangement of results, shows the thought that has been bestowed upon the question of compressing a vast amount of information into small compass and in convenient form for use. This problem has been very successfully solved without the slightest detriment to the value of the work.

Professor PICKERING's own measures with this photometer have now reached the total of 726,952.

R. G. AITKEN.

October, 1913.

DISTRIBUTION OF THE STARS IN DISTANCE FROM THE SUN.

Two articles have recently appeared in the *Monthly Notices*, **73**, 334, 346, upon the distribution of stars in space, or the numbers of stars at various distances from the Sun. In one, DYSON says: If the law of distribution of linear velocities of stars be known, it should be possible by comparison with proper motions to derive the law of distribution of stellar distances. In the other, EDDINGTON says: The problem is to find how the stars are distributed in distance from the Sun.

Two assumptions are made: First that the same law of occurrence of linear velocities holds throughout space; second, that the components of velocity across the line of star-streaming occur according to the law of errors. The first assumption eliminates any relation between the velocities and intrinsic luminosities. The second is well corroborated by observation, as is shown by the following figures derived from the Lick Observatory radial velocities of Class K stars: For velocities between 0^{km} and 5^{km}, the law of errors requires 53 stars, while 55 were observed; between 5^{km} and 10^{km} are found by the law 46, by observation 47; between 10^{km} and 15^{km} by the law 38, by observation 30; between 15^{km} and 25^{km} by the law 27, by observation 30; between 25^{km} and 40^{km} by the law 6, by observation 10; greater than 40^{km}, by the law none, and by observation none. This is one way of showing that observed radial velocities confirm the phenomena of star-streaming.

It is next assumed that the number or proportion of stars at a distance r is an exponential function of r of the form—

$$r \cdot e^{-h^2r^2}$$

in which h is a constant. By comparison with the proper motions of CARRINGTON'S circumpolar stars and of the Boss stars brighter than sixth magnitude, values of the constant have been found which best fit the observations. The function then forms the basis for calculating the number or proportion of stars at various distances, the unit of distance being that corresponding to a parallax of one second of arc. DYSON finds in his discussion of the CARRINGTON circumpolar stars that more than one third of them are congregated between 200 and 400 units of distance or between 600 and 1,200 light-years, and that practically none are beyond a 1,000 units or 3,200 light-years, while only one may be nearer than 40 units or 130 light-years. EDDINGTON, in discussing the stars brighter than sixth magnitude in Boss's Catalogue, has separated the Class A and Class K stars and has divided each class into high and low galactic latitudes. He finds for all these stars in general that between one third and one half of them are congregated between 50 and 100 units of distance or between 160 and 325 light-years. He remarks in discussion of the results that it is not easy to say how reliable they may be, but they indicate one method of attacking the problem. The comparatively small range of distance which includes the great majority of the stars is a noticeable feature. Professor KAPTEYN'S numbers correspond to a distribution considerably more spread out. The present numbers appear to record well with the usual views of stellar distribution; namely, that near the Sun the density of stars is fairly uniform, and that in the plane of the galaxy this uniform distribution extends a great distance, while perpendicular to the plane, the density thins out rather rapidly.

From the results of these discussions of stellar distances, DYSON and EDDINGTON have derived the numbers of stars of various luminosities contained within a sphere of radius corresponding to a parallax of one one-hundredth of a second of arc or 325 light-years. DYSON's figures are 23,000 stars brighter than the Sun, 5,000 more than 10 times the Sun, 1,500 more than 25 times the Sun, 300 more than 50 times the Sun, 24 more than 100 times the Sun, and none more than 200 times the Sun. He concludes that 95 per cent of the CARRINGTON stars are brighter than the Sun and beyond the sphere of 0″.01 of parallax. EDDINGTON's figures, based on the stars of Boss's Catalogue, are for Class K stars only: namely, 2,700 stars between one and 10 times as bright as the Sun, 1,000 between 10 and 100 times the Sun, 100 between 100 and 500 times the Sun, 10 more than 500 times as bright as the Sun, or a total of more than 3,700 stars brighter than the Sun.

G. F. PADDOCK.

October. 1913.

GENERAL NOTES.

A Man-Power Driving-Clock.—The driving-clocks of modern equatorial telescopes are really instruments of precision, and mechanisms of wonderful accuracy, capable, frequently, of maintaining in motion a mass of many tons' weight with a movement so smooth and regular that for minutes at a time there will be no deviation so great as one second of arc. So perfectly does the modern ball-governor clock perform, that the astronomer of to-day has little realization of the mechanical imperfections in spite of which the astronomer of half a century ago managed to secure excellent observations. Perhaps the most unique driving-clock ever used was that employed for LASSELL'S great four-foot reflector at Malta about 1860. To quote from the introduction to his "Observations of Planets and Nebulæ at Malta (*Mem. R. A. S.*, **36**, 2, 1867):—

> "I have not attempted to carry on the telescope by a driving clock, properly so called; as the great weight, amounting to many tons on the bearings [the moving parts weighed about eight tons] makes it a difficult problem. I have, however, a system of wheel-work, terminating in a fly-wheel and winch-handle, which I might almost say answers equally well. The train is so regulated that to give the telescope a sidereal motion it is only necessary to turn this winch-handle once, accurately, in every second. A sort of skeleton clock, giving motion to a loud-beating pendulum, is placed adjacent to the handle, and it is the duty of an assistant (he may be merely a peasant) to take his place at this winch, giving it one revolution for every vibration of the pendulum The fly-wheel, generally, insures the uniformity of each revolution, and a very short initial training is generally sufficient to enable the workman to make the revolutions perfectly coincident with the beats of the pendulum. In some respects this mode of driving is superior to the ordinary mode; for it can be instantly interrupted, or accelerated, or retarded at pleasure, when required for any special purpose The amount of labor is not great, as it may be continued for hours without being oppressive."

One would like to know the peasant's opinion as to the labor involved in making thirty-six hundred regular motions per hour, even though no great force was used in each movement.

> "Two assistants are all that the observer requires, and they are far from being constantly engaged. One or other of them (and they generally interchange during a long night's observation) is occupied pretty

constantly in driving the telescope,—the other, fitfully, in carrying on the [observing] tower, as the telescope retreats from it."

An Institute for Research in Theoretical Astronomy.—So rapid has been the advance in recent years on the practical and observational side of astronomy that no fault can be found with present-day equipments and endowments. The same cannot be said for existing provisions for research in celestial mechanics. Here the disproportion between the number of problems awaiting research and the funds available for carrying on such studies is very great. The layman (and perhaps not a few practical astronomers as well) has but slight idea of the amount of work which is necessary to carry through the larger problems of research in theoretical astronomy, involving the work of master minds in the very limits of mathematical analysis in the first stage, the transforming of these theories to forms suitable for computation as the second, and frequently years of work by computers as the final stage. To mention only one problem: the task of keeping track of the asteroids is becoming a very serious one, and it alone now needs the services of a large and highly trained staff of astronomers.

The Committee on the Minor Planets of the Astronomische Gesellschaft, to meet this need, has outlined in the last number of the *Vierteljahrschrift* a plan for a Research Institute of Theoretical Astronomy.

Great as is the need for such a bureau of research, we fear that some time may elapse before the hopes of the committee may be realized. The plan is an ambitious one; the staff would, as planned, consist of eight theoretical astronomers, ten high-grade computers, thirty routine computers.

The annual budget would total about $50,000, the building would cost about $125,000, and the large sum of $25,000 is specified for computing machines. An endowment of approximately $1,400,000 would be necessary to carry out the scheme on the lines indicated.

A good suggestion is given in the Oxford Notes of *The Observatory* for October, 1913, in discussing the subject of the proposed Research Institute:—

[illegible] theoretical astronomers and computers), however, [illegible] a single institute? This centralization raises many [illegible] the natural one of where the institute is to be [illegible] feature of astronomy is the number of small [illegible] over the globe, many of them at present doing [illegible] existing resources be used in some way? The [illegible] best done single handed, and [illegible] Some unifying principle or sentiment is [illegible] not be beyond the powers of the [illegible] this, as it has already done in [illegible] Catalogues of 187[illegible]."

[illegible] has been appointed Director of the [illegible] as successor to the late Dr. [illegible]

[illegible] has become Director of the Observatory [illegible] St. Petersburg.

[illegible] THE [illegible] OF DIRECTORS OF THE [illegible] OF THE PACIFIC, HELD [illegible] IN THE ROOMS OF THE [illegible] SAN FRANCISCO.

[illegible]

(SEVENTY-EIGHTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur A. SCHAUMASSE, of Nice, France, for the discovery of an unexpected comet on May 6, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

(SEVENTY-NINTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Rev. J. H. METCALF, of Taunton, Massachusetts, for the discovery of an unexpected comet on September 1, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

(EIGHTIETH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur G. NEUJMIN, of Simeis, Russia, for the discovery of an unexpected comet on September 3, 1913.

Committee on the Comet-Medal:
W. W. CAMPBELL,
S. D. TOWNLEY,
H. D. CURTIS.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD NOVEMBER 29, 1913, AT 8:00 P. M., AT CHABOT OBSERVATORY, OAKLAND, CAL.

Vice-President R. G. AITKEN presiding.

Dr. AITKEN made a brief opening address and introduced Mr. CHARLES BURCKHALTER, who made the announcement that the Board of Education of the City of Oakland had decided to remove the observatory to a more favorable location, and that it had been decided by the City of Oakland to secure a 20-inch telescope.

Mr. AMBROSE SWASEY, of the firm of Warner & Swasey of Cleveland, Ohio, was introduced and made a few remarks in reference to the construction of telescopes and astronomical instruments and made special reference to the 72-inch equatorial telescope now being constructed for the Dominion of Canada.

Mr. JOHN A. BRASHAR, the distinguished scientist and lens-maker of Pittsburg, Penn., was then introduced and made an extended and very interesting address on the subject of casting and polishing of telescopic lenses. At the close of his address a vote of thanks was tendered to him for appearing before the Society.

At the close of the meeting Mr. BURCKHALTER invited all present to visit the observatory, where a very fine view of the rings of *Saturn* was observed through the 8-inch equatorial telescope.

D. S. RICHARDSON,
Secretary.

OFFICERS OF THE SOCIETY

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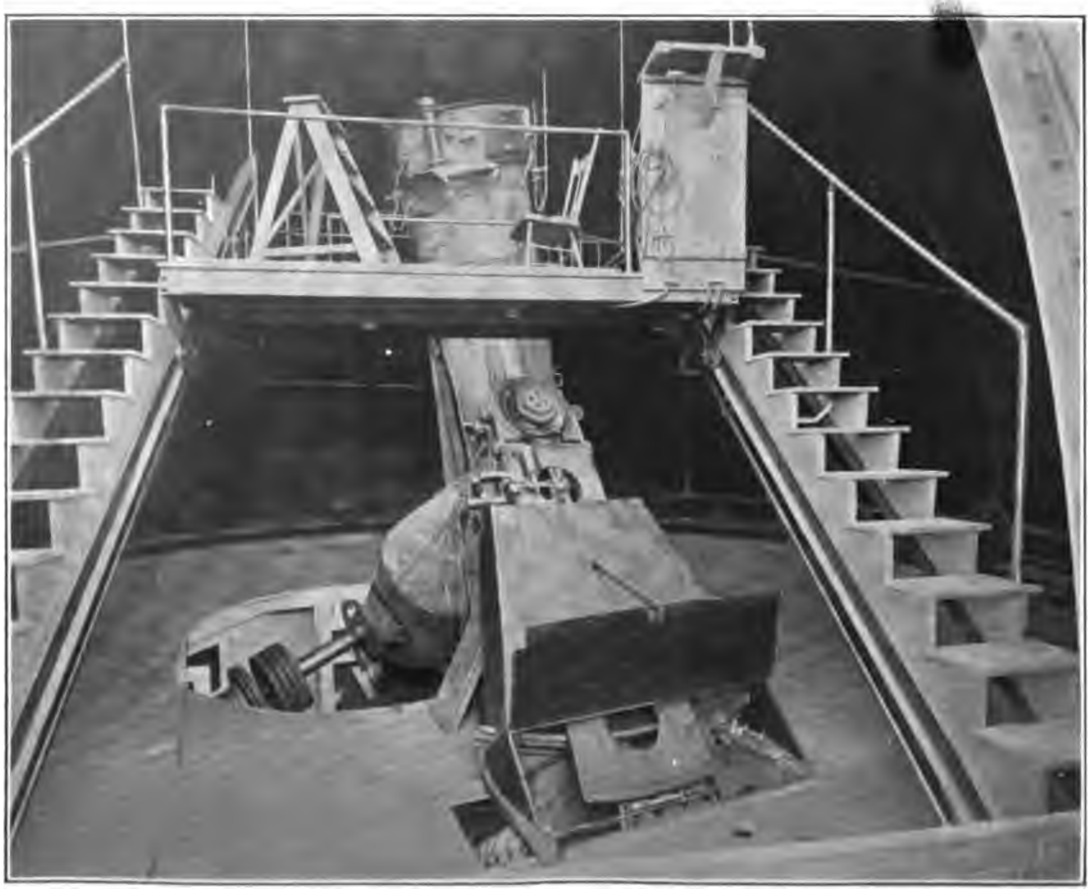

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Naples, Italy, Osservatorio Astronomico.
New Haven, Connecticut, Yale Observatory Observatory.
New York, New York, Columbia University Observatory.
Nice, France, Observatorie.
Northfield, Minnesota, Goodsell Observatory.
Oxford, England, Radcliffe Observatory.
Oxford, England, University Observatory.
Padua, Italy, Osservatorio Astronomico.
Paris, France, Bureau des Longitudes.
Paris, France, Observatoire National.
Paris, France, Rue Cassini 16, Société Astronomique de France.
Potsdam, Germany, Astrophysikalisches Observatorium.
Prague, Austro-Hungary, Universitäts-Sternwarte.
Pulkowa, Russia, Imperial Observatory.
Rio de Janeiro, Brazil, Observatory.
Rome, Italy, Osservatorio Astronomico del Collegio Romano.
Rome, Italy, Specula Vaticana.
San Francisco, Cal., California Academy of Sciences.
San Francisco, Cal., Technical Society of the Pacific Coast.
Stockholm, Sweden, University Observatory.

Strassburg, Germany, Universitäts-Sternwarte.
Sydney, New South Wales, Observatory.
Tacubaya, Mexico, Observatorio Astronomico Nacional.
Tokio, Japan, University Observatory.
Toulouse, France, Observatoire.
University Park, Colorado, Chamberlin Observatory.
University of Virginia, Virginia, McCormick Observatory.
University of Pennsylvania, Upper Darby, Pa., Flower Observatory.
Upsala, Sweden, University Observatory.
Vienna, Austria, K. K. Sternwarte.
Vienna (Ottakring), Austria, Von Kuffnersche Sternwarte.
Washington, D. C., Library of Congress, Periodical Division.
Washington, D. C., National Academy of Sciences.
Washington, D. C., Naval Observatory.
Washington, D. C., Smithsonian Institution.
Washington, D. C., Nautical Almanac, U. S. Naval Office.
Washington, D. C., U. S. Coast and Geodetic Survey.
Williams Bay, Wisconsin, Yerkes Observatory.
Zurich, Switzerland, Observatory.

EXCHANGES.

Astronomische Nachrichten, Kiel, Germany.
Prof. Elis Stromgren, Observatory of Copenhagen, Denmark.
Prof A. A. Nijland, The Observatory, Utrecht, Holland.
Revista de la Sociadad Astronomica de Espana y America, Barcelona, Spain.
Mr. F. Archenhold, Director of Treptow Sternwarte, Berlin, Germany.
Observatorio Astronomico de Cartuja, Granada, Spain.
Prof. L. Praika, Nizbor Observatory, Bohemia.
Prof. Dr. H. J. Klein, Editor of *Sirius*, Theresien St., 85 Köln-Lindenthal, Germany.
Gazette Astronomique, Société d'Astronomie d'Auvers, Rue Pycke 55, Antwerp, Belgium.
Astrophysical Journal, Williams Bay, Wisconsin.
Popular Astronomy, Northfield, Minn.
The Observatory, Greenwich, England.
Revista di Astronomia, Società Astronomica Italiana, Turin, Italy.
Orion, Strada Rosca No. 3, Rucarest, Roumania.
Journal Astronomique, Observatoire de Lille, Hem, France.
Astronomia Popolare, Palazo Madama, Turin, Italy.
Società Astronomica Italiana, Rue Maria Vittoria 23, Turin, Italy.
The Journal of the British Astronomical Association, care F. W. Levander, 30 North Villas, Camden Square, N. W., London, England.
Monthly Notices, Royal Astronomical Society, London, England.
American Mathematical Society, 501 West 116th St., New York, N. Y.

Società degli Spettroscopisti Italiani, Catania, Italy.
Sociedad Cientifica "Antonio Alzate," Mexico, Mexico.
Solar Observatory, Mount Wilson, via Pasadena, Cal.
American Philosophical Society, 105 South Fifth St., Philadelphia, Pa.
Harvard College Observatory, Cambridge, Mass.
The Monthly Evening Star Map, 150 Nassau St., New York, N. Y.
The Astronomical Herald, Tokyo, Japan.
Publication of Pomona College, Claremont, Cal.
The Astronomical Journal, Albany, N. Y.
Journal de Physique, 5 Rue de la Santé (13^e), Paris, France.
Journal of the Royal Astronomical Society of Canada, 198 College St., Toronto, Canada.
Ciel et Terre, 24 Avenue des Villas, Bruxelles, Belgium.
Sociedad Astronomica, Diagonal 462.2, Barcelona, Spain.

THE AWARD OF THE BRUCE MEDAL TO DR. J. O. BACKLUND.

By ALEXANDER McADIE.

In accordance with the vote of the Directors, acting on the recommendations of the nominating astronomers at home and abroad, it becomes the pleasant duty of the retiring President to announce the award of the Bruce Gold Medal of the Society to Dr. JOHANN OSKAR BACKLUND, Director of the Russian Royal Observatory, at Pulkowa. Dr. BACKLUND is the eleventh recipient of the medal, and it is of interest to know that he makes the list of medalists more truly international in character, representing in himself both Sweden and Russia. Germany, Great Britain, Italy, France, Holland, and the United States are already represented, and South Africa, if we credit Sir DAVID GILL to the Cape of Good Hope. Like many distinguished American astronomers, BACKLUND has exacting administrative duties, due to his position as Director of a large observatory. He does not represent what might be called the popular type of astronomer, but rather the painstaking, thoroly patient investigator, content to take some difficult problem and give, if necessary, a life-time to the solution.

A professional astronomer alone can do justice to BACKLUND's work; and your President, not being such, has felt it wise to rely upon the kind assistance of a former recipient of the Bruce Medal, Professor E. C. PICKERING.

BACKLUND's chief research work has been in connection with the determination of the motion and brightness of Encke's Comet, the earliest discovered short-period comet and one that, with the exception of Halley's Comet (a long-period comet), has been more closely studied than any other. First seen in 1786 by MÉCHAIN and MESSIER, the comet was rediscovered by Miss CAROLINE HERSCHEL in 1795. In 1805 PONS, HUTH and BOUVARD saw it on the same day. In 1818 PONS rediscovered it, and in 1819 ENCKE showed that it moved in an elliptic orbit with approximately a three-year period. By 1820 he was able to show that the period was diminishing.

To quote from Professor NEWALL[1]:—

> "In BODE's *Jahrbuch* for 1826 (May, 1823) comes ENCKE's first serious consideration of a resisting medium, which NEWTON had never discountenanced and which LAPLACE and EULER had not succeeded in demonstrating. ENCKE there quotes from a letter of OLBERS, written in answer to his inquiries, a passage relating to the possible comparability of the density of the comet and the density of the material of the zodiacal light; and thus, whereas the earlier papers of ENCKE have titles which refer to PON's comet—a name which he always adhered to, in spite of the remonstrances of BODE and many others—the title of his last (1858) summary of work on the subject (*Berl. Jahrbuch,* 1861, abstracted in English in *M. N.,* xix, 70-75) is 'On the existence of a resisting medium in space.'"

The comet reappeared in 1822, 1825, and 1828, its perihelion passages being calculated in advance on the basis of the existence of a resisting medium. The assumptions were that the resistance of the medium was proportional to its density and the square of the velocity of the comet; also that the density of the medium varies inversely as the square of the distance from the Sun. The action of the medium on the comet was represented by a tangential force given in a certain equation. In brief, the argument was that the motion of Encke's Comet, especially the gradual increase in the mean motion, could be accounted for on the assumptions made above. The argument, however, was not satisfactory in connection with planetary perturbations. After ENCKE's death the problem was carried further by von ASTEN and Dr. E. BECKER. Von ASTEN went to Pulkowa in 1870 and continued the investigation of the theory of the motion of Encke's Comet on the basis of absolute perturbations.

Von ASTEN died in 1878, and from that time unto the present Dr. BACKLUND has continued the work. Finding that the apparitions of 1871-1881 contradicted previous hypotheses and rather suggested that the constant of resistance had changed, BACKLUND determined to calculate afresh the whole series of perturbations from 1819. Thru the support of the Academy of Sciences of St. Petersburg and the generosity of M. E. NOBEL he published in six volumes the perturbations of the orbit due to the planets *Mercury, Venus,* Earth, *Mars, Jupiter,* and *Saturn* from 1819 to 1891, embracing twenty-two revolutions and twenty-three apparitions of the comet. The first result was that with regard to acceleration, the twenty-three apparitions could not be connected as a whole; and the period was therefore divided into three parts: 1819-1858, 1858-1871, 1871-1891. The main results in brief are that the acceleration was on an average constant during 1819-1858, diminished in 1858 and in 1868, and was again constant in 1871-1891. In addition to these changes, a well-established periodic change occurs at least in the interval 1819-1858. Further, the mass of *Mercury* appears to be well determined. The value 1/9,700,000 must be considered as a close approximation to the truth; and the mass of *Venus* is possibly less than the assumed value 1/401,839.

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[1] *Monthly Notices R. A. S.,* 69. 324, 1909.

To quote again from Professor NEWALL:—

> "Dr. BACKLUND has considered the hypothesis that the comet crosses a meteoric ring in the neighborbood of the perihelion; but he rejects it as improbable in many respects, and as incapable of explaining many particulars. He points out that the greatest outstanding errors occur in the perihelion passages in 1828, 1838, 1848, which were years of great sun-spot activity. About 1858 the first abrupt change in the acceleration took place, and 1860.1 is registered as a year of maximum solar activity. The change in 1868 is not far from the maximum of 1870; and lastly, the well-determined abrupt change of 1895 is close to the maximum in 1894. It seems that these coincidences can hardly be mere chance. But Dr. BACKLUND regards his task as completed when astrometry in his hands has been made to deliver up all the facts at present attainable with respect to the kinematics of the comet. We can well imagine with what satisfaction Dr. BACKLUND views the disappearance of the long-outstanding difficulty with regard to the derived mass of *Mercury*, the constancy of which offered such a splendid guarantee for the accuracy and trustworthiness of the whole investigation.

While his work on Encke's Comet has been his chief investigation, a work which by itself won the award of the Gold Medal of the Royal Astronomical Society in 1909, BACKLUND has made many other notable contributions to theoretical astronomy. Among these may be mentioned his investigation on the motion of minor planets of the *Hecuba* type, carried on along the lines laid out by GYLDÉN; a defense of GYLDÉN'S method against attacks by other theoretical astronomers; and a valuable investigation of the Theory of Precession and Nutation, in which he succeeded in a development, where LAPLACE, STOCKWELL, and ADAMS had failed. In this the long-period periodic planetary terms caused trouble. LAPLACE and the others failed because they sought to find the general solution, retaining the long-period periodic terms, and wishing to derive the planetary terms through ordinary quadratures. BACKLUND, on the other hand, succeeded by not separating them from the nutation terms, but by deriving them in the same way as the long-period elementary terms in his treatise "Ueber die Bewegung kleiner Planeten vom Hecubatypus."

In closing, I wish to mention some of the other honors that have been conferred upon our medallist. In addition to the award of the Gold Medal of the Royal Astronomical Society, to which reference has been made, he was honored by Cambridge University in 1904, when he was awarded its "Doctor in Science" *honoris causa.* Four other eminent scientists—namely, DAVID GILL, NORMAN LOCKYER, WILLIAM RAMSAY, and ARTHUR SCHUSTER—were given the same degree by Cambridge at this time. In 1905 the honorary Doctorate was conferred by the University of Kapstadt upon BACKLUND and G. H. DARWIN, DAVID GILL, and J. C. KAPTEYN.

THE GREAT AND THE SMALL—PRESIDENTIAL ADDRESS.

BY ALEXANDER MCADIE.

Members of the Astronomical Society of the Pacific:

By a wise unwritten law of this Society, a layman is elected President every alternate year. In the present instance, the wisdom of the custom is not so readily apparent, and your President, conscious of short-comings even in the modest role of layman, tried his best to escape the honor which his fellow directors saw fit to offer. As a layman, however, it has been his rare privilege to know well many astronomers, and because of their patience and forbearance he has absorbed certain information which leads him to believe that astronomy, pre-eminently the science of vast dimensions, is none the less vitally concerned with aerology, a new science and one of comparatively limited distances.

The thickness of the Earth's atmosphere, compared with the diameter of the Earth, is as a sheet of tissue paper to the thickness of a good-sized book. Compared with the Sun's diameter, the ratio would be tissue paper to one hundred volumes; or, to the distance of the Sun, as tissue to one hundred times the hundred volumes; and, finally, if we compare the depth of the atmosphere with the distance to the nearest star, the ratio would be something like a sheet of paper to thirty-six hundred rows of books, each row containing a million volumes. Plainly, astrometry, compared with aerometry, is as the great to the small; and one might hastily infer that our atmosphere is a negligible quantity. Yet the greater is sometimes dependent on the less, and from astronomers themselves we gather that they have their troubles due to the Earth's atmosphere; for did not the President of the Royal Astronomical Society, speaking at the annual dinner of the Royal Meteorological Society not long ago, say, half jocularly, half in earnest, that the "ideal world of the astronomer would be a world in which no atmosphere existed and there were no science of meteorology and no meteorologists"? Undoubtedly, this would be the easiest solution of certain problems from the astronomical point of view, if it were not that astronomers, like other people, must live.

It was in California, it will be remembered, that an early attempt was made to free the astronomer from some of his troubles due to dust-laden atmosphere and the aberration of the image by non-homogeneous air strata. In the history of the Lick Observatory, we have a striking illustration of increased efficiency due in part to favorable atmospheric environment. Again, at the Mt. Wilson Solar Observatory, an institution devoted specially to the study of the one near star, our Sun, the necessity of a pure and steady atmosphere has been shown to be all-important. The latter observatory and the Smithsonian Astrophysical Observatory have, thru unusual atmospheric opportunities, virtually developed a new field of research, one as yet without a name and for which until a more appropriate name shall be given we propose "solclimatics," asking forgiveness for the violence done our mother tongue.

In this field, where research practically began with LANGLEY's work in determining the value of the solar constant and the coefficients of absorption for various radiations, checked by his observations at Mt. Whitney, such questions as the relation of seasonal abnormalities of pressure and temperature, precipitation with variation in the solar output, and, in brief, all questions relating to climate control by variation of solar output, will call for co-operative work by aero-physicist and astronomer. The former must furnish whatever data are required relating to air movement, the absorption and radiation of heat at various levels in the atmosphere, and the departures due to the presence of water vapor. Nor can the aerologist longer content himself with assumed conditions and employ formulæ and equations of limited application. He must deal with the atmosphere as it is; that is, as modern exploration is showing it to be, a non-adiabatic atmosphere and not a dry, pure, perfect gas.

At this point reference may properly be made to the units now coming into use in aerological work. In the *Monthly Weather Review* for August, 1908, there appeared a paper by MCADIE on the need of more rational units in aerology; and giving an original method of recording pressure variations in percentages or permillages of a standard atmosphere. The paper was extensively commented upon and aroused much discussion. In the *Monthly Weather Review* for March, 1909, Dr. W. KÖPPEN, Director of the Deutsche Seewarte at Hamburg, pointed out that if pressure were measured in bars or millibars, as employed by BJERKNES, SANDSTROM, and others, the advantages of the percentage system proposed by MCADIE would be realized, with the additional gain that all pressures would be expressed in dynamic units. In other words, KÖPPEN's proposal was to use, instead of sea-level pressure, the pressure normally found at a height of 348 feet, or 106 meters. This would change, then, from the former barometric standard of 29.92 inches, or 760 millimeters (at latitude 45°), which in force units would be 1,013,303 dynes, to the even 1,000,000 dynes, corresponding to reading 29.53 inches, or 750 millimeters. Dr. KÖPPEN also presented to the Aerological Congress at Monaco in April, 1909, a strong plea for the use of dynes. During 1909 and 1910 the writer urged the adoption of these units by the U. S. Weather Bureau, but without success. In the *American Journal of Science* for October, 1910, and in other publications he has shown the advantages resulting from the adoption of these units. In 1910 there was published by the Carnegie Institution the first volume of "Dynamic Meteorology and Hydrography," by the well-known investigator, V. BJERKNES and collaborators. BJERKNES significantly says:—

> "In meteorology it is common to give the barometric pressure in millimeters or inches of mercury. The millimeter division is not in the least more rational than the division into inches. Neither of them has anything to do with absolute units. The consequences of this irrationality have not yet been severely felt because the barometric records have until now served for qualitative purposes mainly."

So far as known to me, no actual use of the new units (pressure in millibars and temperature in degrees absolute centigrade) was made in the United States except by the writer, at San Francisco in the period 1909-1913.[1] In Europe, under the progressive leadership of such eminent meteorologists as KÖPPEN, SHAW, ASSMANN, DINES, GOLD, CAVE, and others, the units have come into general use. Daily and weekly weather reports give pressure in millibars.[2] On January 1, 1914, the U. S. Weather Bureau began to employ these units in a daily weather map of the northern hemisphere. The following table, devised at Blue Hill Observatory, has been found convenient and may be helpful in astronomical observatories where pressures are still read in inches and fractions thereof. Copies of these conversion tables and similar tables for converting readings in millimeters may be obtained from the Director of the Blue Hill Observatory of Harvard University. In this table the first column gives the height of the barometer, in inches, for every tenth of an inch from 29.0 to 31.0. The second column gives the corresponding pressure in millibars when 1,000 is added. The remaining columns give the pressures in millibars at intermediate heights at intervals of 0.02 inches. It is to be remembered that the base is no longer sea-level, but altitude 106 meters:—

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[1] *Scientific American Supplement*, Dec. 6, 1913.

[2] *Nature*, Oct. 16, 1913.

BASE PRESSURE 1,000,000 DYNES OR 1,000 MILLIBARS.

Pressure in millibars = 1000 +.

Barometer in inches.	.00	.02	.04	.06	.08
29.00	— 18.0	— 17.3	— 16.6	— 16.0	— 15.3
29.10	— 14.6	— 13.9	— 13.2	— 12.6	— 11.9
29.20	— 11.2	— 10.5	— 9.9	— 9.2	— 8.5
29.30	— 7.8	— 7.2	— 6.5	— 5.8	— 5.1
29.40	— 4.4	— 3.8	— 3.1	— 2.4	— 1.7
29.50	— 1.1	— 0.4	+ 0.3	+ 1.0	+ 1.7
29.60	+ 2.3	+ 3.0	+ 3.7	+ 4.4	+ 5.0
29.70	+ 5.7	+ 6.4	+ 7.1	+ 7.7	+ 8.4
29.80	+ 9.1	+ 9.8	+ 10.5	+ 11.1	+ 11.8
29.90	+ 12.5	+ 13.2	+ 13.8	+ 14.5	+ 15.2
30.00	+ 15.9	+ 16.6	+ 17.2	+ 17.9	+ 18.6
30.10	+ 19.3	+ 19.9	+ 20.6	+ 21.3	+ 22.0
30.20	+ 22.6	+ 23.3	+ 24.0	+ 24.7	+ 25.4
30.30	+ 26.0	+ 26.7	+ 27.4	+ 28.1	+ 28.7
30.40	+ 29.4	+ 30.1	+ 30.8	+ 31.5	+ 32.1
30.50	+ 32.8	+ 33.5	+ 34.2	+ 34.8	+ 35.5
30.60	+ 36.2	+ 36.9	+ 37.5	+ 38.2	+ 38.9
30.70	+ 39.6	+ 40.3	+ 40.9	+ 41.6	+ 42.3
30.80	+ 43.0	+ 43.6	+ 44.3	+ 45.0	+ 45.7
30.90	+ 46.4	+ 47.0	+ 47.7	+ 48.4	+ 49.1
31.00	+ 49.7	+ 50.4	+ 51.1	+ 51.8	+ 52.4

Example: Barometer reading 29.62 inches, convert to millibars. Tabular correction for 29.60 + .02 is + 3.0. Pressure in millibars is 1000 + 3.0 = 1003.0.

Beginning with the familiar equation connecting pressure, P, volume, V, temperature, T, and gas constant, R,—

$$PV = RT,$$

the height of the so-called homogeneous atmosphere,—that is, the thickness of the stratum which our entire atmosphere would form if compressed to a uniform density equal to the average density at the base level (106 meters above sea) and at temperature zero centigrade ($= 273°$ Abs.),—can be found thus, in meters:—

$$\frac{13.596 \times 0.750}{0.001293} = 7886;$$

the three numerical factors being, in order, the density of mercury, the pressure reading, and the specific weight of air. We may call the value approximately 8,000 meters. The gas constant *R* is obtained by dividing by 273. If pressures are given in millibars, the value of *R* is 2.87×10^7. But these values are for dry air and need further correction. The volume of the atmosphere is approximately $4{,}080 \times 10^{18}$ cubic meters; or, since a cubic meter of dry air at 273° A. and standard gravity weighs 1.293 kilograms, the weight of the atmosphere in round numbers is $5{,}200 \times 10^{15}$ kgs. This is about 1/1,125,000 of the Earth's mass.

If we determine the approximate height of the *sensible* atmosphere by the disappearance of the twilight arch (18° below the horizon) we have Earth's radius multiplied by the secant of 9°, less 1, or $h = R\ (1.0125 - 1) = 0.0125 \times 6{,}370{,}191$ meters $= 79{,}627$ meters. This must be corrected for refraction, and the final value would be about 64,000 meters, or eight times the depth of the homogeneous atmosphere. As we have already said, the depth of the atmosphere compared with any astronomical dimension is no more than a leaf of thinnest paper to miles of books. Still the instruments of the astronomer are emplaced in this paper. For the most part, they are at the very bottom of the atmosphere. True, in some States, as in California and Arizona, instruments are used at high levels. At Mt. Wilson and Pasadena comparative work can be done at levels of 1,493 dynamic meters and 247 dynamic meters, respectively; in other words, thru a range of one fifth of the effective atmosphere. And it is feasible to work an appreciable part of the year at elevations as high as 4,500 dynamic meters. The summit of Mt. Whitney is at 4,329 dynamic meters, or 4,419 meters above sea-level, where the pressure is but 0.6 that at the basal plane. St. John of Mt. Wilson has shown that there are several spectrum lines which are displaced in measurable degree by a difference of pressure of two tenths of an atmosphere. The point is referred to, only to show that the atmosphere cannot be disregarded in ultimate determinations of wave-lengths, frequencies of vibration, and standards of length.

The most important outcome of recent exploration of the air by kites and sounding balloons is the establishment of the two great layers which are best known by the names troposphere and stratosphere. Theoretically, when dry air is lifted to a level where the pressure is reduced one-half, there should be a cooling of 50° C. In fact, and especially near mountain peaks, very different results are found. But even the adiabatic rate does not hold. This we shall return to later.

Numerous records of soundings have been published by the International Commission for Scientific Aerostation. We give one of the latest records made at the observatory at Uccle, Belgium, June 9, 1911, during pleasant weather. A height of 31,780 d. meters (32,430 meters) was reached. The lowest temperature was given by one thermometer (Hergesell) as 212° A. (—61° C) at 13,040 meters, while the balloon was rising, or 213° A. by the other thermometer (Kleinschmidt) at 12,600 meters, while the balloon was descending.

The following skeleton table may be interesting:—

Time	Pressure		Elevation	Temperature	Gradient	R. H.
	mb	mm	Met.	Abs.		
7:00	1,001	751	100	290°	...	81
7:05 (?)	900	675	1,000	287	...	..
....	797	598	2,000	281	.056	..
....	705	529	3,000	275	.066	51
7:18	621	466	4,000	269	.042	34
7:20 (?)	547	410	5,000	264	.069	..
....	479	359	6,000	251	.086	30
7:34	313	235	9,000	234	.084	30
7:38	271	203	10,900	222	.065	..
7:44	199	149	12,000	216	.039	29
7:47:04[1]	168	126	13,040	213	.021	29
7:48	160	120	13,340	213	—.007	29
7:52	129	97	14,650	218	—.031	30
7:56	103	78	16,050	223	—.07	29
8:02	72	54	18,370	218	.01	29
8:12	36	27	22,720	222	.00	29
8:32	8	6	32,430	234	...	29

The adiabatic gradient generally employed is 9.87° C. per kilometer. For 5.5 kilometers, therefore, the fall in temperature would be about 54°. But the rate holds only for small changes; and, as DINES[2] has pointed out, the formula "in fact is only true for the supposed case of convective equilibrium which, so far as dry air is concerned, never exists in practice for any large change of height." He gives the following departures for different heights, assuming average conditions:—

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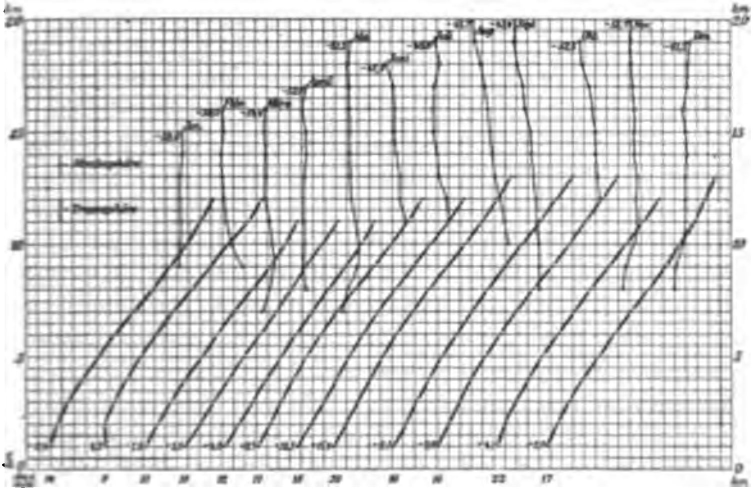
[1] Beginning of inversion.

[2] *Quar. Jour. R. Met. Soc.*, July, 1913, Vol. XXXIX, No. 167, page 187.

1^{km}	0°.3 C	9^{km}	7°.6 C
2	0 .6	10	9 .7
3	1 .0	11	11 .3
4	1 .8	12	13 .9
5	2 .6	13	16 .7
6	3 .5	14	19 .8
7	4 .5	15	25 .0
8	6 .0		

Temperature, then, does not fall as rapidly as the law requires and the pressure at a given level is greater than that given by formula. BIGELOW[1] shows that the gas coefficient *R*, while a constant in the adiabatic system, is a variable in the non-adiabatic system. In other words, the specific heat is a variable in non-adiabatic air. This means that no account is



MEAN TEMPERATURE FOR EACH MONTH, WITH STRATOSPHERE AND TROPOSPHERE LIMITS.

From G. NADLER, in *Beiträge zur Physik der freien Atmosphäre.*

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[1] *American Journal of Science*, Vol. XXXIV, December, 1912.

taken of circulation or of radiation of heat. He very properly says "that the gravity, pressure, and circulation terms, as computed from the observations in cyclones, anti-cyclones, and in the general circulation, do not conform; and all the efforts of meteorologists to make them do so have been failures or fictitious and improper solutions."

From the results of nearly two hundred soundings made during 1906-08, NADLER has summarized the mean temperature at various levels for each month and also the average limits of the troposphere and stratosphere. (See diagram.[1])

What precedes shows that a ray of light traversing the atmosphere does not come thru a homogeneous medium nor thru one of uniformly decreasing density. This must materially affect the values of the coefficients of refraction as ordinarily given. As to measuring the heights of mountains by vertical angles (theodolites), it is interesting to know that other methods presumably less accurate have given truer heights. Thus, in measuring the heights of Mts. Whitney Shasta, and Rainier, the results obtained by the writer, using atmospheric pressure methods, were nearer the true elevations than those obtained with theodolites by the engineers. Again, in measuring the high peaks of Asia (to which Professor E. C. PICKERING has called my attention) the British geodesists found that all angles of elevation to high peaks, measured from the plains of India and from the outer hills, were too large. This is strikingly shown in the case of Mt. Everest, where all measurements from low-lying stations make the mountain over 30,000 feet, while all measurements from the high levels make the mountain less than 30,000 feet. Refraction is the cause of the difference, and coefficients suitable for low levels are not accurate for high air work. According to BURRAD and HAYDEN, refraction is greatest in the morning and evening and least in the middle of the day. It is different in summer from winter.

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[1] The figures beneath the diagram (*Anz. d.* and *Aufst.*) indicate the number of soundings upon which each monthly curve is based. The figures at the right and left express the altitude in kilometers, and those on the diagram itself, the temperatures in degrees C. For example, 15 sounding balloon ascensions in July gave average temperature of + 11°.3 C. at altitude one kilometer. The temperature decreased up to altitude 12 kilometers, and then remained almost constant, or increased slightly to altitude 19 kilometers, temperature — 48°.8 C.

TUCKER, in *Lick Observatory Bulletin*, No. 231, has discussed the diurnal variation in the refraction at Mt. Hamilton, using observations for a period of nearly twenty years. He finds a slight but distinct difference between the refraction effect in the daylight and night hours that does not depend upon the pressure, temperature, or change of temperature during the observing hours. He suggests that the physical explanation may lie in the rapid changes in the surface strata as compared with slower changes in higher levels near the time of sunrise and sunset, so that the readings of the thermometers in the air strata near the Earth's surface are not representative of the temperatures in overlying strata. Evidently soundings of the atmosphere near Mt. Hamilton might show frequent and marked inversions of temperature.

Again, there are many questions connected with the transparency of the air. For example, the successful use of the photo-electric cell, which promises so much in photometric measurements, must be affected by any rapid variations in air transparency. Can the aero-physicist be of service to the astro-physicist in this rapidly developing field?

Meteorology had its beginning under the sheltering domes of astronomy. Altho men live in the air, they seem to have been interested more in the motions of the stars than in the movements of the medium in which they lived. After many years of waiting came the Burgomaster of Magdeburg, with his air-pump; then GALILEO, inventor of thermometer as well as telescope; and after him TORRICELLI, with the barometer. What instruments are we still waiting for that shall help us to a better understanding of this envelope of gases and water-vapor, relatively small in itself, but meaning so much to the development of astronomy?

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THE ASTRONOMICAL ACTIVITIES OF PROFESSOR GEORGE DAVIDSON.

By W. W. Campbell.

George Davidson was born in Nottingham, England, on May 9, 1825. Coming to the United States when a boy, he completed the course of study in the Central High School, Philadelphia, in 1845. He entered the service of the United States Coast Survey on June 1, 1845, residing in Washington as secretary to Superintendent Bache. He also served as a computer and in other capacities.

The needs of navigation for accurate knowledge of the Pacific coast-line were recognized by the authorities in Washington shortly after the territory of California was acquired from Mexico. The first requirements were determinations of the latitudes and longitudes of the prominent capes, headlands and entrances to the harbors, hydrographic surveys of the harbors, and topographic surveys of harbor surroundings. Davidson was the oldest member and the leader of a party of three, consisting of himself, John Rockwell and James S. Lawson, sent to the Pacific Coast shortly after the discovery of gold in California, for the purpose of starting the accurate work of the Coast Survey in this region. The party arrived in the summer of 1850. With the exception of five years, coinciding approximately with the Civil War, Davidson's home was in San Francisco continuously until the date of his death, December 2, 1911. His life was devoted with untiring energy and complete unselfishness to the interests of science on the Pacific Coast. It is no exaggeration to say that during sixty years his name was more familiar to the scientifically-inclined inhabitants of the Pacific Coast region than that of any other resident.

His services were not confined to the requirements of the Coast Survey work. His efficient help was always available to advance any department of science. He was president of the California Academy of Sciences for sixteen years, and president of the Pacific Geographical Society for thirty years. He gave assistance in all lines of investigation undertaken by the Academy. He was an authority on the voyages of the early explorers of the Pacific Coast and on the early history of the Coast. At various times and during periods of different lengths he served on the Irrigation Commission of California, on the Advisory Harbor Improvement Commission for San Francisco, on the Mississippi River Commission, on the United States Assay Commission, as Regent of the University of California, and during the last years of his life as Professor of Geography in the University of California. In June, 1895, he resigned his position in the Coast Survey, at the conclusion of fifty years of service. During the last twenty-seven years of this period he was Assistant in charge of all Coast Survey operations on the Pacific Coast of the United States. His interests in the welfare of the community where he resided were always active and available, and he had the unconscious personal charm and magnetism which made and held strong friends. A worthy biography of Professor DAVIDSON would embrace the wide range of subjects already mentioned, and it is hoped that a competent pen will some day undertake the duty of writing it.

While all branches of knowledge interested Professor DAVIDSON, the subject of astronomy, pure and applied, seemed to make a special appeal to him. He was an authority in the geodetic applications of astronomy; and the reports of the United States Coast Survey show that he never failed to grasp opportunities for making observations promising to be useful in any branch of pure astronomy. The list of his published contributions contains many titles relating to eclipses, meteors, occultations and comets, and to atmospheric conditions affecting astronomical observations. His influence with JAMES LICK, while Mr. LICK was formulating plans for erecting the most powerful telescope in existence, was wise and potent, and perhaps even vital to a practical solution of Mr. LICK's problem. A review of DAVIDSON's activities in pure and applied astronomy, necessarily abbreviated, is herewith presented. There is little doubt that a review of his geographical work would show equally extensive contributions in that field.

Assistant DAVIDSON's first observing station on the Pacific Slope, in 1850, was located at Point Conception, the most prominent and dangerous angle in the western coast-line of the United States. He determined the latitude and longitude of the station, the variation and dip of the magnetic needle, and reported upon the best location for the proposed light-house in that neighborhood. During the first four years other stations were occupied successively at Monterey, San Diego, Cape Disappointment (at the mouth of the Columbia River), Port Orford, Neah Bay (near the entrance to Puget Sound), at the Presidio of San Francisco, and at approximately twenty minor points. The longitudes of the principal stations were determined from observed positions of the Moon with reference to neighboring stars (Moon culminations), and from the observed times of occultations of the stars by the Moon, and the relative longitudes of the minor stations were determined by the transportation of chronometers. The modern methods of determining longitudes by telegraphic signals were of course not available. Coastwise travel in those days was by sailing vessels, and surf landings were unavoidable at many stations on the capes and points. There were occasionally personal risks from hostile natives, as at Neah Bay, where the observations were made from behind breastworks with men and guns constantly ready to repel attack.

The astronomical, magnetic, hydrographic and topographic data which were accumulated with extraordinary rapidity were woven by him into a report, as early as 1855, and issued as a guide to mariners. In the Coast Survey report for the year 1858 the superintendent refers to DAVIDSON's Directory for the Pacific Coast, as follows: "This useful work has been compiled by GEORGE DAVIDSON, Esq., Assistant in the Coast Survey, from the Coast Survey and other authentic data, embodying also the results of his own experience on the Coast, where he has been occupied in charge of geographical, triangulation and topographical parties since the commencement of the survey in 1849. Having thoroughly and peculiarly identified himself with the survey of the western coast from its beginning, and had occasion himself to know the necessities, facilities and dangers of its navigation, he has been in a position to prepare a particularly valuable directory for the use of mariners and navigators."

The partial solar eclipse of May 26, 1854, was observed with a small telescope, chiefly for times of contacts, by Mr. DAVIDSON from his station at Humboldt Bay. He observed the occultations of twenty-two stars of the *Pleiades* group on March 1, 1857, to strengthen the longitude determination of the San Francisco station. He observed, at San Francisco, the times of beginning and ending of the partial solar eclipse of March 25, 1857. He observed occultations of the *Pleiades*, March 26, 1860, on Ross Mountain, and the times of contacts in the partial solar eclipse of July 18, 1860, on Sonoma Mountain.

Mr. DAVIDSON was ordered to the Atlantic Coast service of the Survey late in the year 1860, where he remained until about 1866. After the purchase of Alaska from Russia, he was ordered to make a survey of the coast of Alaska with reference to the needs of navigators. The materials for this Directory were rapidly collected, in 1867, and this extensive work was published promptly. He was appointed assistant in charge of the Pacific Coast work of the Survey in 1868.

Mr. DAVIDSON'S intensive work on the astronomical foundations of the Pacific surveys called his attention strongly to the weak points in existing instruments employed by the Survey, and his inventive genius suggested many improvements. A description of the DAVIDSON meridian instrument for determining time, longitude and latitude is published in the Survey report for 1867. This instrument was extensively used in subsequent work of the Coast Survey thruout the United States.

The construction of the Union and Central Pacific Railways and the establishing of telegraphic connection between the Atlantic and Pacific Coasts enabled the longitude determinations on the Pacific Coast to be placed upon an accurate basis for the first time. The Pacific end of the longitude comparisons with Harvard College Observatory was conducted by Mr. DAVIDSON in a temporary observatory set up for the purpose in Washington Square. Telegraphic signals were exchanged with Cambridge on twelve nights, between February 15 and April 4, 1869, through the courtesy of the Western Union Telegraph Company.

The total solar eclipse of August 7, 1869, was observed by Mr. DAVIDSON and his party on the Chilkaht River, Alaska. The times of contact were satisfactorily estimated and careful descriptions of eclipse phenomena were prepared and published.

In appreciation of Mr. DAVIDSON's services, the Regents of the University of California appointed him Honorary Professor of Geodesy and Astronomy in the University, dating from 1873.

In 1870, at the San Buena Ventura station, he recorded the flight of 556 meteors, and made a special report on the subject.

During a few weeks in the mid-summer of 1872 he occupied a station at Summit, the highest point on the Central Pacific Railway in the Sierra Nevada Mountains, altitude 7,200 feet. He tested the astronomical conditions as affecting astronomical observations, and was greatly impressed with the advantages of a high altitude. His report in the Coast Survey volume for 1872 places emphasis on the subject.

The transit of *Venus* had been observed in 1769 by M. CHAPPE DE L'AUTEROCHE at San Jose del Cabo in Lower California, but this observer had not determined, or at least had not published, the exact position of his observing station. On account of the interest attached to the transits of *Venus* which would occur in 1874 and in 1882, Mr. DAVIDSON in 1873 searched for the exact location occupied by DE L'AUTEROCHE. Though no evidences of the latter's occupation remained, the description of the observing station enabled Mr. DAVIDSON to locate the station, in his opinion, within a space of twenty feet square, and the co-ordinates of the observing station were accordingly determined.

Professor DAVIDSON was appointed by the United States Government Commission to observe the transit of *Venus* in Japan on December 8, 1874. Assisted by TITTMANN and EDWARDS, of the Survey, the preparations were carefully made, but unfortunately the expedition was rendered unfruitful by clouds at the critical times.

The total solar eclipse of January 11, 1880, was carefully and extensively observed from the summit of Santa Lucia Mountain by a Coast Survey party under Professor DAVIDSON's direction, and likewise by Professor FRISBIE of the United States Naval Observatory. All the observations were visual, and the results related to the estimated times of contacts, the appearances of the corona, prominences, etc.

He was appointed by the Government Transit of *Venus* Commission to direct the work of one of the parties for the observation of the transit of 1882. The observations were obtained successfully at Cerro Roblero, New Mexico.

His party observed the transit of *Mercury* at the Yolo Base, Sacramento Valley, on November 7, 1881.

Catalogs of star positions suited to the work of the Coast Survey field parties were compiled by DAVIDSON from time to time. The Report of the Survey for 1883 contains a catalog of 1278 time and circumpolar stars arranged for this purpose.

In the late 1880's the question of the variation of terrestrial latitudes was prominent, and observations at widely separated stations were urgently called for. As a labor of love Professor DAVIDSON undertook the observations of latitude pairs, by the Talcott-Horrebow method, at his observatory in San Francisco. Between May, 1891, and August, 1892, approximately 2500 pairs of stars were observed for this purpose; to be exact, 5308 observations on 283 stars were secured. An additional series of observations was made by him in the years 1893-94. The results agreed with those secured at European, Atlantic Coast and Hawaiian stations, confirming the fact that the latitudes of points on the Earth's surface are constantly changing by minute amounts.

Professor DAVIDSON's programs of observation, whether for the determination of latitude, time and azimuth, of magnetic declination and dip, of refraction constants, or for research in pure astronomy on his own account, were characterized by the very great numbers of observations planned for and secured, as well as by the observance of precautions for ensuring that the individual observations be as accurate as possible.

It is a remarkable fact that the first investigating astronomical observatory planned for California, and in fact for the western half of the United States, the Lick Observatory, was on a large scale for its time. The first observatory *completed* in California, however, was that of Professor DAVIDSON. This was established in LaFayette Park, San Francisco, about 1879. It was erected at DAVIDSON's personal expense. It contained a 6.4-inch Clark refracting telescope. This instrument was used to observe the total solar eclipse of January 11, 1880, on Santa

Lucia Mountain; to observe several partial solar eclipses and the 1882 transit of *Venus;* to make drawings of the principal planets; and to observe star occultations and comets. The observatory was dismantled several years ago, following a permanent affection of Professor DAVIDSON's eyesight, which prevented him from making further observations.

There remains to be considered Professor DAVIDSON's relations to JAMES LICK and to the proposed Lick Observatory; and there can be no doubt that here also he rendered most useful service to the advancement of science. Professor DAVIDSON has prepared and published two statements describing these relations. The first one, prepared in 1892, is brief, and is contained in Dr. MILICENT W. SHINN's account of the founding and early scientific work of the Lick Observatory, in the *Overland Monthly* for November, 1892. Dr. SHINN is an editor of great ability, possessing well-balanced historical judgment, based upon a thoro university training, who was intensely interested in all questions relating to the origin of Lick Observatory. In preparing her historical article she fortunately had the advantage of personal interviews with Professor DAVIDSON, and of submitting the proof sheets to him. I quote from her paper:—

> No one seems to know how or when the idea of a great telescope entered Mr. LICK's mind. It was there before he took any one into his confidence. . . . In February, 1873, he quite unexpectedly offered the Academy a piece of land on Market Street, the site of its present building. Professor GEORGE DAVIDSON, then president of the Academy, called to thank him, and Mr. LICK then told him of his purpose of leaving money for a great telescope. . . . Mr. LICK had no knowledge whatever of any of the auxiliaries needed by a telescope, or of the purposes of astronomy beyond bare discovery; and all this was left to Professor DAVIDSON to outline to him in the few months of their conferences. Out of the very interesting verbal narrative that Professor DAVIDSON has given me of this episode, he is willing to have in print at present only so much as is contained in the following memoranda, which he wishes me to leave in his (Professor DAVIDSON's) own words:
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> "I am not willing, at this time, to write the narrative of my relations with JAMES LICK from February, 1873, to August, 1874, but I give very briefly the following items of interest:
>
> "JAMES LICK originally intended to erect the Observatory at Fourth and Market Streets. His ideas of what he wanted and what he should do were of the very vaguest character. It required months of careful

approaches and the proper presentation of facts to change his views on location. He next had a notion of locating it on the mountains overlooking his mill-site, near Santa Clara, and thought it would be a Mecca,—but only in the sense of a show.

"Gradually I guided his judgment to place it on a great elevation in the Sierra Nevadas, by placing before him the results of my experimental work at great elevations, as well as the experience of other high-altitude observers. At the same time, by my presentation of facts and figures of the cost and maintenance of other observatories, he named the sum of $1,200,000 in one of his wills, as the sum to be set aside for founding the James Lick Observatory, and for its support.

"In making him acquainted with the size and performance of the telescopes of the larger observatories, I naturally mentioned the great reflector of Lord Rosse. That seemed to fire his ambition, and at the next interview he insisted on a refractor of six feet in diameter. It required long and patient explanations to get him down to forty inches, which was the diameter we finally adopted.

"In October, 1873, I obtained his permission to make known to the California Academy of Sciences the main facts of his intention to place the largest refracting telescope that could be constructed at an elevation of 10,000 feet in the Sierra Nevadas. I have not the announcement within reach, but it was published in the *Alta California* late in October, I think the 21st. A short time before that I had confidentially made the facts of Lick's intention known to Leland Stanford and his wife.

"An eminent astronomer had nearly frustrated the whole project by urging Mr. Lick to adopt a reflecting telescope instead of a refractor; but he had a remarkably clear mechanical mind, and I had very little trouble in satisfying him of the weakness of the suggestion.

"Before I went to Washington for consultation with other observers for the transit of *Venus* expeditions in 1874, Mr. Lick held to the decision of the refractor at a great elevation, and details had been decided upon, although he had several times changed his will in other matters. Before departing I showed him that by the Code of California he could not then devise by will to any corporate body, and urged him to make a deed of trust.

"Upon my return I found he had made the deed of trust, and that some of the Pioneers had prevailed upon him to locate the observatory on the north shore of Lake Tahoe; and had prevailed upon him to reduce the $1,200,000 to $700,000.

"When he again changed his views, and determined to locate the observatory on the vastly inferior site of Mount Hamilton, I declined further conference with him.

"The whole of my intercourse with him was full of curious and interesting, and sometimes dramatic, incidents, that have never been sought by any one professing to write the history of the Lick Observatory."

Professor DAVIDSON's second article, prepared in 1899 and published in the *University of California Magazine* for April, 1899, is too long for reproduction here. It is, in effect, an expansion of the memorandum prepared by him for Dr. SHINN's paper, as quoted above in full. It confirms all the important historical points in the memorandum. However, it is desirable to quote those of Professor DAVIDSON's sentences which relate to Mr. LICK's announcement of his plans for a great telescope. ". . . but my first meeting with Mr. LICK was in February, 1873, when another member and myself carried to Mr. LICK the thanks of the Society [California Academy of Sciences] for his unsolicited and munificent gift. After that meeting and at the request of Mr. LICK, my conferences with him were very frequent. . . . He kept himself thoroughly informed on what the Academy was doing, and seemed especially interested in astronomical matters, although he had never looked through a telescope or read a work on astronomy. In time he disclosed his intentions about a great telescope."

Professor DAVIDSON's point of view was clearly that of the intensely interested astronomer who desired to see the bequest expended in a practicable manner. The advice to construct a refractor instead of a great reflector was quite in harmony with astronomical opinions prevailing at that time, and the plan to construct a refractor six feet in diameter must certainly have failed. Whether the advice to select a location for the observatory in the Sierra Nevada Mountains, at an elevation of 10,000 feet, was wise and practicable, may be open to question at the present time, but this was certainly Professor DAVIDSON's strong and honest point of view. Over the misfortune that the promised sum of $1,200,000 was reduced by Mr. LICK to $700,000 we need not moralize. From the many side-lights thrown upon Mr. LICK's character, it is entirely possible that without Professor DAVIDSON's guidance at a critical period the plans for the construction of a useful telescope and observatory might have come to grief. It is also clear from the fact that Mr. LICK stood by his plans, notwithstanding his displeasure with his first board of trustees, resulting in their resignation, and in the appointment of a second board and finally of a third board, that Mr. LICK was determined to get his telescope. We may all unite in expressing gratification that Professor DAVIDSON'S duties in the matter were performed so conscientiously and with unselfish singleness of purpose. The Lick Observatory was undoubtedly more successfully planned by virtue of Professor DAVIDSON'S help than it would have been without this help.

Professor DAVIDSON retained a strong interest in all astronomical subjects to the end. His death marked the passing of a great and useful man.

THE CÓRDOBA ZONES AND DURCHMUSTERUNG.[1]

BY C. D. PERRINE.

In 1891 Dr. THOME commenced the observations to continue the A. G. zone catalogs from — 22° to — 37°. The observing work was completed in 1900. The reduction and revision work is now completed. The first 5° zone (— 22° to — 27°), comprising 15,075 stars, has been sent to the printer. The second 5° zone will be completed, ready for printing, by the end of the present year. The third zone will be finished about the end of 1914.

It seems highly desirable that this zone work should be extended to the pole as quickly as possible. In looking about for a quick method I have come to the conclusion that photography offers great advantages and am planning to continue the work by this means. It may be of interest to give an outline of the proposed plan.

The photographs will be taken with a doublet of 18^{cm} aperture and 110^{cm} focal length, stopped down to about 12 or 13^{cm} to cover sharply a field 5° on a side, if possible.

For the zone catalog work it is planned to take overlapping plates, as is done for the astrographic work—so that a final catalog position will be the mean of four images. This should give, with the scale adopted, a satisfactory degree of accuracy. I expect the probable error of a single image to be not over a second of arc and perhaps no more than a half second. The usual astrographic reseau will be used.

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[1] Report presented at the Hamburg meeting of the Astronomische Gesellschaft, August, 1913.

If the accuracy of the positions derived from the photographs is sufficient, it is probable that the fundamental stars will be observed with our new meridian circle, otherwise the fundamental star-places will probably be taken from the Córdoba General Catalog.

The negatives will be obtained on orthochromatic plates to approximate more nearly to the visual scale of magnitudes. Two images of each star will be obtained for measurement, with exposures of about ten minutes each. In addition, there will be made a third exposure of sufficient length to show an average 9.0 star, which will be the limiting magnitude. This third image will also serve to check the transparency and the steadiness of the air.

In the measurement of the plates, only stars will be measured which have three images. This is a plan which I have used in the work of the Córdoba astrographic zones and which has been found most useful. In the astrographic work a *fourth* exposure is used to check the transparency of the sky and the "seeing," the third exposure being just sufficient to show an 11.0 magnitude star (the limit to be measured).

The faintest star to be measured will have at least five times the exposure necessary to show the faintest image of it. This is to obtain greater accuracy in the positions, as it is known that images at the limit of vision are only composed of a few darkened silver grains which do not yield accurate positions.

It may be urged that the result aimed at in the above plan could be secured by taking the measures of the 9.0 and brighter stars of the astrographic zones and preparing a catalog. I have considered this and have come to the conclusion that the special work necessary for the zone catalog can all be done in much less time than it will take to secure the remainder of the astrographic plates and their measures.

It may be of interest to add a short account of the state of the Durchmusterung work and of the work recently undertaken at Córdoba of preparing a catalog of all of the stars of 9.5 and brighter between —82° and the pole. The positions for this catalog will be determined with the 5-inch meridian circle, and the magnitudes will be determined photometrically. This catalog is intended to furnish a zone catalog of that region and also to answer for the same region in the Durchmusterung.

The Durchmusterung zone —52° to —62° is practically completed, and it is expected to begin the printing of the catalog about October 1, 1913.

It is expected to finish the original Durchmusterung plan by observing the region between —62° and —82° as soon as the zone —52° to —62° is completed.

The maps of the zone —22° to —42° will all have been republished about the end of the present year. The completion of the catalog for the zone —52° to —62° will make available the necessary data for the maps of —42° to —62° and these will be undertaken as quickly as possible. The remaining maps (—62 to the pole) will be completed as soon as the observations become available.

Observatorio Nacional Argentino,
Córdoba, July 12, 1913.

SETH CARLO CHANDLER.

By R. H. Tucker.

One of the most brilliant minds in American astronomy passed away at the close of the month of December. For the greater part of his life, Dr. Seth Chandler had devoted his time and energy to the investigation of astronomical problems, without material support from any outside source, and without holding any scientific or university appointment. In the late sixties he had been connected with the Coast Survey, practically as a special assistant to Dr. B. A. Gould; and in the early eighties he held an appointment at the Harvard College Observatory. During this last epoch he computed and distributed the greater part of the elements of comet orbits, with the resulting ephemerides, and kept up a service for the prompt circulation of astronomical news. The code for the transmission of astronomical telegrams, which he compiled soon after, with RITCHIE, has only lately been practically superseded.

The pressure of his family affairs prevented his joining Dr. GOULD in 1869, for the expedition to the southern hemisphere, that was to result in the foundation of the Argentine National Observatory at Córdoba, and in such impressive contributions to astronomy. On the return of Dr. GOULD, sixteen years later, the early intimacy and scientific co-operation of the two astronomers were renewed, and the years that ensued, up to the date of GOULD's death, were probably CHANDLER's most happy and fruitful ones. The enthusiasm and zeal of the younger man were balanced and restrained by the judgment and wide experience of the elder, and it was a privilege to see the two minds in action, each responding to the stimulus of the other.

An immense amount of work was accomplished by CHANDLER in the investigation of the latitude variation, reducing and discussing old observations, and the establishment of the final accepted form of the variation is practically entirely due to his researches. He chose to attack the problem independently, without regard to previously accepted theory. Without testing for any definite period, he treated the existing observational material with the period as an unknown. The result gave the fourteen-month term, superimposed upon the annual term, and these satisfy the accepted movement of the pole, with very slight deviations. The outstanding deviations may be due to systematic errors of observation, like those involving a change in refractions, or to the existence of some other small term in the variation, like that known by KIMURAS' name, but these deviations are extremely small.

Investigation of the aberration, and of the fundamental constants of astronomy, came in as by-products in the steady grind upon the variation of latitude.

In variable-star discussions, Dr. CHANDLER was an authority of first rank, tho never as an observer. His work upon the subject had been admirably classified, and put in order, and every available source of information in regard to any particular star can be conveniently and quickly looked up in his library of variable stars.

After Dr. **Gould**'s death, **Chandler** became the editor of the *Astronomical Journal*, founded by **Gould** in 1849, but suspended between 1861 and 1885. As associate editors, Professors **Aspah Hall** and **Lewis** Boss were joined, in the early years. After 1908, Professor Boss became principal editor, with **Chandler** and others as associates. But **Chandler**'s health had been severely broken, mainly by the excessive and unrestrained zeal with which he worked in his most active periods, and the last few years have been practically spent in retirement, with little hope of rehabilitation.

He was sixty-seven years old, having been born and educated in Boston. He was an actuary in insurance for many years, and held important posts of private and corporate trust. He received the Watson medal of our National Academy of Sciences and the gold medal of the Royal Astronomical Society of England, as recognition of his notable contributions to astronomy.

JOHN ROBIE EASTMAN.

By R. H. Tucker.

Another one of the coterie of astronomers that gave substantial reputation to the Naval Observatory at Washington died in September last. Professor J. R. **Eastman** had been retired, at the naval age limit of sixty-two years, in 1898, tho his promotion to the rank of rear admiral came some eight years later.

He was born at Andover in 1836 and was graduated from Dartmouth in 1862, the college that later gave him the degrees of M. S. and Ph. D. He obtained a position as assistant astronomer at the Naval Observatory soon after his graduation, and three years later was promoted to the rank of professor of mathematics in the U. S. Navy.

The staff of the observatory in those years included among its distinguished names those of **Newcomb**, **Hall**, **Holden**, **Harkness**, **Frisby**, **Skinner** and **Paul**. Of these Dr. **Holden** is now at West Point, Professors **Frisby** and **Skinner** are retired, and Professor **Paul** is at Annapolis.

The work of Professor EASTMAN was mainly done with the meridian circle, at an epoch when the greater part of the resources of the principal observatories was devoted to observations of star positions and the resulting discussion of stellar motions. The great national observatories will still continue in this line, undoubtedly, along with the observations of Sun, Moon, and planets. Privately endowed observatories are taking up the astrophysical researches more and more, and photography is extending the measurement of star positions to those of the fainter classes.

The greater part of EASTMAN's work is contained in the Second Washington Catalog, published in 1898 (Appendix I, Wash. Obs. 1892). The observations were made with the old Pistor and Martins transit circle of 8½ inches aperture, and were reduced to the epoch 1875.0, the epoch of many other sets of observations of that period.

In 1878, nearly the entire staff of the Naval Observatory went to Colorado to observe the total eclipse of the Sun, and Professor EASTMAN was of the party. Among other astronomers of this country who probably had their only eclipse experience at that time were Boss and SAFFORD. Those were the days of visual observations only, and the collection of sketches of the corona, made often by hands unskilled in graphical work, shows a wide variety of impressions.

In 1882 our government fitted out eight parties for the observation of the transit of *Venus* in various parts of the world, and Professor EASTMAN was ordered with his party to Florida. A French expedition, chaperoned by Mr. PRESTON of the Coast Survey, also observed the transit in Florida.

Professor EASTMAN had been vice-president of the American Association for the Advancement of Science, and president of the Washington Academy and of the Washington Philosophical Society. He was seventy-seven years of age at the time of his death.

PLANETARY PHENOMENA FOR MARCH AND APRIL, 1914.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter	Mar. 4,	9^h 3^m P.M.	First Quarter	Apr. 3,	11^h 41^m A.M.
Full Moon	" 11,	8 18 P.M.	Full Moon	" 10,	5 28 A.M.
Last Quarter	" 18,	11 39 A.M.	Last Quarter	" 16,	11 52 P.M.
New Moon	" 26,	10 9 A.M.	New Moon	" 25,	3 22 A.M.

The second eclipse of the year, a partial eclipse of the Moon, will occur on March 11th. It will be visible generally thruout out the United States. It is nearly total, the maximum obscuration being 92 per cent. The principal circumstances are as follows, Pacific time:—

Moon enters penumbra	March 11,	5^h 41^m P.M.
Moon enters shadow	" 11,	6 42 P.M.
Middle of the eclipse	" 11,	8 13 P.M.
Moon leaves shadow	" 11,	9 44 P.M.
Moon leaves penumbra	" 11,	10 45 P.M.

The Sun passes the vernal equinox and spring begins March 21st, 3 A. M. Pacific time.

Mercury on March 1st is an evening star, setting about an hour and a quarter after sunset, and may therefore be seen under good weather conditions; but this condition lasts only a few days, as the planet rapidly approaches inferior conjunction, which it reaches on the morning of March 10th, and becomes a morning star. It then moves out toward greatest west elongation, reaching this on April 6th, when its distance from the Sun is 27° 46′. This greatest elongation is much greater than the average greatest, as it occurs only one day after aphelion passage; but as the planet is more than 10° south of the Sun at this time, the interval between the rising of the planet and of the Sun will at its best be scarcely more than an hour, and the conditions for visibility are therefore not good. The planet will then gradually approach the Sun, being well on toward superior conjunction by the end of the month. *Mercury* will be in conjunction with *Venus* on March 6th, passing it 5° 28′ to the north.

Venus is an evening star, having passed superior conjunction with the Sun on February 11th, but will not be easy to see during early March on account of its nearness to the Sun. It will set less than half an hour after sunset until near the middle of the month. Its apparent distance from the Sun increases somewhat rapidly, and by the end of April the interval between the setting of the Sun and of the planet will be more than an hour and a half. It will therefore be an easy object during April, but will not be nearly as conspicuous as it will be during the autumn, when its real distance from the Earth will be much less. On April 1st its distance from us will be 155,000,000 miles, and at the time of greatest brightness next October its distance will be only 40,000,000 miles.

Mars is still in fine position for evening observation, remaining above the horizon until half-after three on March 1st, and until nearly 1 A. M. on April 30th. During the two months it moves about 24° eastward and 5° southward from the constellation *Gemini* into *Cancer*. About the middle of April it is about 5° south of *Pollux*, *β Geminorum*, a position less than 1° south of the position it held in December, 1913. Since its opposition in January its path has been several degrees north of the ecliptic, and on March 22d reaches its greatest heliocentric latitude north. Its brightness is rapidly growing less, being on March 1st only 41 per cent of that at opposition and on April 30th only 16 per cent. On March 1st its distance from the Earth is 88,000,000 miles, only a little less than the Earth's mean distance from the Sun, and by the end of April its distance from the Sun is 140,000,000 miles. On April 26th it is in aphelion, its distance from the Sun being on that date 155,000,000 miles.

Jupiter is a morning star, and is now far enough away from the Sun to be easily visible. It rises shortly after 5 A. M. on March 1st and at a little before 2 A. M. at the end of April. It is in the constellation *Capricorn* and moves about 12° eastward and 3° northward during the two months.

Saturn is still in good position for evening observation, altho it sets earlier. On March 1st it sets somewhat after

1 A. M. and on April 30th at a little before 10 P. M. Its general position in the sky is about two hours west of *Mars*. It is in the constellation *Taurus*, and on March 1st is about 5° north and east of the first-magnitude star *Aldebaran*, *α Tauri*. During March and April it moves about 5° eastward and 1° northward. As seen in the telescope the ratio of minor to major axis of the rings remains about the same, a little less than one half.

Uranus is a morning object, rising about an hour and a half before sunrise on March 1st and at about half-after one on April 30th. It is in the constellation *Capricorn* and moves about 2° eastward and a little northward during the two months. It is very close to *Jupiter* early in March, the planets being in conjunction on March 4th about 1 A. M. Pacific time. *Uranus* is then only 9′ south of *Jupiter*. The planets will separate rather slowly, about 10′ daily, *Jupiter* moving relatively faster eastward, and by the end of April *Jupiter* will be about 8° east of *Uranus*.

Neptune is in the evening sky, setting about 4:30 A. M. on March 1st and at about 12:30 A. M. on April 30th. It is on the border-line between the constellations *Gemini* and *Cancer*. It will be in conjunction with *Mars* on April 21st, the latter passing 2° 34′ north of *Neptune*.

(EIGHTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. P. T. Delavan, of La Plata, Argentina, for the discovery of an unexpected comet on December 17, 1913.

Committee on the Comet-Medal:
W. W. Campbell,
S. D. Townley,
H. D. Curtis.

NOTES FROM PACIFIC COAST OBSERVATORIES.

IMPROVEMENTS IN THE CROSSLEY MOUNTING.

When the Crossley reflector was presented to the Lick Observatory in 1895 the mounting, which dated back to about the year 1880, was found to be lacking in the rigidity and steadiness necessary for successful photographic work. Many excellent photographs were secured with it in this form, but there were also many failures due primarily to the deficiencies of the mounting. It was accordingly remounted in 1905.[1] The change was a very complete one; to-day, absolutely all that remain of the original instrument and equipment as it came from England are the dome, the 36½-inch mirror, and the iron bucket which holds the lead clock weights.

The original mounting, as is well known, was of the fork form; for the new mounting Dr. PERRINE wisely chose the English equatorial form, with a long polar axis supported by a pier at each end. He was anxious to secure as long a driving arm as possible, to give great steadiness of movement, and so adopted the plan of driving by two sectors of 8-foot radius. The details of this double-sector drive were ingeniously worked out: there are two exactly similar sectors and driving worms; and while one sector is driving, the other is reversing at a slightly greater speed, so that the effect of a nearly continuous drive was secured. However, several minutes were lost each hour, as it was necessary for the observer to leave his guiding twice in this interval, once to stop the reversing sector at the end of its reverse, and once to change from one sector to the other. With sector A driving and sector B reversing, for instance, the cycle of operations was as follows:—

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[1] *Lick Observatory Bulletin*, **3**, 124, 1905.

1. Stop motion of B at end of reverse.
   Interval of about fifteen minutes.
2. When A reached end of drive, cover plate, and move a shift lever, which caused both worms to drive.
3. Clamp in sector B.
4. Unclamp sector A.
5. Finish movement of shift lever; B now driving, A "dead."
6. Move another lever to cause A to reverse.

A movement of a lever in any way out of this specified order would stop the clock instantly, and this occasionally happened in the sleepy morning hours.

The change from a single central pier to the two piers of the new mounting necessitated the discarding of the rising platform of the original Crossley mounting, and in its place recourse was had to an upper floor with a large central opening. On this upper floor were two sliding sections, which could be moved out some distance over the central opening, and to reach the eye end in various positions of the telescope a six-foot and a nine-foot ladder were available. But in many positions of the telescope the use of this method entailed great strain and fatigue on the part of the observer; north of the zenith the only method available was a rather precarious plank scaffold stretched over the polar axis from one ladder to the other. The amount of labor involved in constant ascents and descents of these ladders when picking up faint objects, and in changing sectors and manipulating the dome, the sliding floor sections, and the ladders with changing hour angles, can be appreciated only by those who have worked with the instrument. It is only fair to Dr. PERRINE to state at this point that he always had in mind the installation of equipment to make the work of observing easier, but financial limitations at that time rendered necessary the adoption of less expensive expedients.

In February, 1910,[1] the instrument was dismounted and anti-friction roller-bearings were put in on both polar and declination axes, with other minor improvements. These changes added very greatly to the ease of motion of the telescope. Bearings of the same type had previously (1906) been put on the declination axis of the 37-inch Mills reflector at Santiago, but, so far as I know, this application to the Crossley was the first case in which such bearings were used thruout for a heavy instrument with the entire elimination of all friction wheels, counterpoises, and ordinary bearings. The old fear that such roller bearings would fail to give sufficiently steady motion or sufficient permanency of adjustment has been found to be entirely groundless, and the bearings of several large reflectors now being constructed will be of similar type.

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[1] *Publications A. S. P.*, **22**, 40, 1910.

With regard to the unique double-sector drive, were the instrument to be rebuilt, it is probable that a full worm wheel giving perfectly continuous drive would be used instead of the double-sector plan. Room for a wheel of sufficiently large radius would be secured by mounting it on a southern prolongation of the polar axis. This change in design would be made solely on the grounds of greater simplicity and to secure the advantages of a perfectly continuous drive, for the present sectors are equivalent to a driving wheel sixteen feet in diameter, and they drive beautifully.

When plans were made in May, 1913, to increase the efficiency of the Crossley accessory equipment, some thought was given to the project of discarding the present sectors and of mounting a full worm wheel inside the south bearing of the present polar axis. But the available bearing space for such a wheel is very small; the wheel would have had to be of a crowned or bell shape; the change would have made necessary a practically new clock; and the expense, particularly of the time necessary to grind up a new wheel which should drive as perfectly as the present sectors, seemed prohibitory. It was accordingly decided to keep to the present form of drive and to install an electrically-operated automatic sector-changer instead. At the same time designs were made and work was started on an adequate observing platform, an electric slow motion in right ascension, and electric clamps.

The general appearance of the changes made is shown in the accompanying photograph (see frontispiece). The observing platform is ten feet long by four and a half feet wide. It travels on wheels moving inside the flanges of two six-inch I-beams, which make an angle of 42° with the horizontal. The distance of vertical travel of the platform is ten feet. The platform is raised and lowered by a one-half horse-power motor at the bottom of the frame, not visible in the picture. Long screws are used to raise and lower the platform, as this plan is self-locking, and no counter-weights are provided. The long screws have ball-thrust bearings at the upper ends, and are supported at the middle by bearings which automatically recede to allow the nuts fastened to the platform to pass by. Under the steps at the right are nine trolley wires, which carry the circuits from the platform to the dome and platform motors. Limit switches are provided to stop the platform automatically at its highest and lowest points. The controllers for moving the dome and the rising platform are located on the front of the small desk at the right end of the platform. The structural iron framework of the steps and platform support is rigidly attached to the dome and revolves with it. From the top of the steps a raised walk encloses the telescope on three sides. This is never used in ordinary observing, but is provided for emergencies in work at the zenith on special spectrographic or other problems which might necessitate unusual orientations of the movable end-section of the tube. A one-fourth horse-power motor has been installed to open and close the shutter. The endless cord for the slow motion in right ascension, which too often entangled itself on bolts or projections, has been supplanted by a small motor connected with the clock train by worm gearing.

The general scheme of the electric clamps can be clearly seen in the cut. Powerful solenoids, one for each sector, apply pressure to the clamp block through levers. Catches driven by springs and attached to the plungers of smaller unclamping solenoids are driven forward when the clamp lever reaches its highest point and hold it there. In unclamping, the smaller solenoid pulls back the catch and allows the clamping lever to fall.

The upper portion of the automatic sector-change mechanism may be seen through the small opening in the floor; this opening, as well as the worms, are kept covered during work. A full description of this mechanism could be given only with the aid of its working drawings. In brief, it consists of a strong shaft driven by worm and gearing from a small motor so as to make one revolution in about twenty seconds. This shaft carries three cam wheels six inches in diameter; also a cylindrical commutator whose segments are properly shaped to give the necessary intermittent action in connection with contacts made by the sectors at each end of their travel. Twelve spring contacts bear on the commutator segments and provide for the automatic action of the cam shaft and shift gears, for the automatic clamping and unclamping when sectors are changing, and also provide selectively for the clamp switch at the eye end of the telescope, so that when one sector is driving only that sector may be clamped or unclamped by the observer. Roller-pins in the cam grooves give motion to the three rods which move the shift gears in the worm mechanism; the points of the shifting gears are chamfered as in automobiles, and in addition the rods are provided with spring joints, which give them one quarter of an inch play against strong springs. A full description of the intermittent action of the commutator and cams is unnecessary; it is sufficient to say that it goes through all the operations of the cycle in correct order, clamping and unclamping the proper sectors when the change is being made, is apparently infallible, and is entirely automatic, the observer giving no thought to the matter except to cover the plate with a light flap during the eight seconds needed for the change and until he again brings the guiding star up to the crosswire. During this change of sectors a red light goes on and a warning bell rings. It is possible to take up the unavoidable small "drift" of the guiding star with the electric slow motion and be guiding again 15 seconds after the warning bell starts to ring, which makes the drive practically continuous.

To avoid long cables in the electrical connections on the telescope tube the ten wires needed terminate in two sets of plugs at the upper end, one on each side of the tube, and are also carried to a similar bank of plugs at the lower end of the telescope. With the exception of the switch for manipulating the shutter, every operation is controlled either from the platform or from the eye end of the telescope, so that the observer need not leave the platform during a night's work. As direct photography with the instrument is carried on in entire darkness ruby lights are placed at the front corners of the platform in parallel with the dome and platform controllers, so that the observer may be able to avoid striking the telescope when moving either the platform or the dome.

Among minor conveniences two may be mentioned which have been in use for several years: the right-angled finder (a disused comet seeker), and a counterbalanced mirror cover controlled by a cord over pulleys at the eye end so that the mirror may be quickly and easily covered when putting in or taking out a plate in positions near the zenith. The broken finder, in particular, has proved itself absolutely indispensable in actual work.

With the exception of the original mounting of the Crossley reflector, where the services of an assistant were necessary, all the Lick Observatory instruments have always been on the "one-man" plan, *i. e.* no assistant or helper is ever employed in the ordinary work of the 36-inch refractor or of the reflector, and experience has shown that the observer's personal convenience and freedom from fatigue, and the ability to cut down to a minimum the time and effort in starting work or changing from one object to another are factors fully as important as the possession of powerful equipment. In these respects the recently installed Crossley improvements have very greatly increased the efficiency of the instrument.

HEBER D. CURTIS.

FAINT STANDARDS OF PHOTOGRAPHIC MAGNITUDE FOR THE SELECTED AREAS.

The purpose of this note is to describe briefly a program of photometric observations now in progress with the 60-inch reflector of the Mt. Wilson Solar Observatory. It involves the determination of the photographic magnitudes of the fainter stars immediately surrounding the central star of each of the 115 Selected Areas on and north of the celestial equator. The regions covered are 23′ in diameter, and it is proposed to determine upon an absolute scale the magnitudes of all the stars that may be registered with an exposure of 15 minutes. With satisfactory observing conditions, the limiting magnitude should be about 17.5 on the photographic scale. Altho the main interest of the investigation centers in the faint stars, it is important for comparison purposes that the brighter objects should also be observed. On this account plates of short exposure are included. An absolute scale is established for each region by means of diaphrams and a wire gauze screen. The program for each area is as follows:—

Exposure Time, Min.	Apertures	No. of Plates
2	60, 32, 14, 9, 9, 14, 32, 60	2
15	60, 32, 32, 60	1
15	60, screen, screen, 60	1

Of the 460 plates required for the determination of the relative magnitudes, 225 have already been obtained; and of this number one half have been measured and reduced.

The results will be reduced to a homogeneous system by inter-comparison and comparison with the pole. The program for this part of the observations has not been definitely determined. A tentative arrangement provides for the inter-comparison of the areas of each zone by photographing adjacent areas on the same plate with exposures of two minutes. In this manner each zone can be reduced to a homogeneous system. To reduce all the zones to the same zero point, comparisons with the pole will be made, probably at intervals of four hours in right ascension. To avoid the direct comparison of widely distant areas, secondary standards will be established in the 30° and 60° zones, which will serve for the determination of the zero points of the zones of small and intermediate declination.

An indication of the amount of material which will thus be accumulated is afforded by the fact that the photographs for ten areas ranging from 20° to 72° of galactic latitude show 864 stars, an average of 86 per area. On this basis, the final results should include magnitudes for nearly 10,000 stars.

The probable precision of a single value of a magnitude, including scale errors, is of the order of 0.09 magnitude. As an average of four values will be available for each star, the mean probable error of a catalog magnitude should be about 0.05 magnitude. FREDERICK H. SEARES.

MT. WILSON SOLAR OBSERVATORY,
December 12, 1913.

NOTE ON THE DOUBLE STAR Ho 229.

In 1886, HOUGH, with the 18½-inch Dearborn telescope, noted a faint star 3″ north of the 6.0 star B. D. + 14°.1235 (1880.0 R. A. 6^h 11^m 16^s; Decl. + 14° 26′). He made no measures, and the pair was neglected until DOOLITTLE undertook the remeasurement of all the Ho stars. His note is: "Examined on many perfect nights [1901-1906], but no companion seen. No prior measures. . . . I think it very probable that the companion has no real existence."

On the night of January 10, 1914, however, I found the companion a fairly easy object to measure; one that could not escape notice in a telescope even smaller than the 18-inch of the Flower Observatory. Apparently there has been a change, since 1906, either in the brightness of the small star or in its distance from the primary. My measure gives the position:—

1914.027 325°.5 2″.31 6.0 — 12.5 36-inch, seeing 2

R. G. AITKEN.

NOTE ON COMET *f* 1913 (DELAVAN).

The sixth comet of the year 1913 was discovered by DELAVAN at La Plata Observatory, Argentina, on December 17th. Tho described as "visible in a large telescope," it was seen at Mt. Hamilton on December 18th with the 3-inch finder of the 12-inch equatorial. The comet is small, with a sharp nucleus and without a tail. Clouds prevented an accurate measure of position on that night, and moonlight and stormy weather made it impossible to secure any on later dates. An approximate position secured by Dr. HAYNES on January 19.75 G. M. T. gives R. A. 2^h 42^m ±; Decl. — 3° 9′ ±. This does not agree at all well with the predicted places from any of the published orbits.

R. G. AITKEN.

THE 20-INCH TELESCOPE FOR THE CHABOT OBSERVATORY.

The new equatorial for the Chabot Observatory has advanced to the point where it is in actual course of construction; the WARNER & SWASEY COMPANY having been the successful bidders for the entire telescope. The optical parts will be made by the JOHN A. BRASHEAR COMPANY.

The objective will be of Jena glass, with a focal length of 28 feet. The circles will have both coarse and fine graduations, and they and all parts of the instrument will have full electric illumination. The position micrometer will have an 8½-inch circle. The driving clock will be wound by electric motor. A sidereal circle and quick motion in right ascension will be provided; also two finders — a short focus of 3-inch aperture and a standard focus of 4½-inch aperture.

The discs for the objective have been ordered and the mounting is already under way, for the WARNER & SWASEY COMPANY intend to place it in the Panama-Pacific Exposition. At the close of the exposition it will be brought to Oakland and installed in the new building.

The work on the building and the removal of the present equipment will begin in the autumn of this year.

The site has not yet been selected, several having been offered free of cost. Two of these are entirely satisfactory from an astronomical standpoint, possessing unusual freedom from fog and having intervening hills cutting off the lights from the city.

CHARLES BURCKHALTER.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these *Publications*, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

A NEW METHOD OF MEASURING SMALL DISPLACEMENTS OF SPECTRUM LINES.

Bulletin No. 32 of the Kodaikanal Observatory contains an important article by the Director, JOHN EVERSHED, describing a new method of measuring spectrograms.

The essence of the method consists in making a positive copy of the negative plate to be measured, in placing this positive copy, reversed end for end, almost in contact with the ordinary negative, and in moving the positive with reference to the negative so that the positive images of the lines coincide successively with the negative images of the corresponding lines. The positive measuring plate is adjusted in a special instrument so that there is a 0.05^{mm} separation of the two plates. The accuracy of the adjustment for coincidence of the two images of the lines depends upon the sensitiveness of the eye in estimating the change for the bright and dark contiguous images of a line, to the perfectly uniform density which results when the positive image exactly coincides with the negative. Mr. EVERSHED finds that the delicacy of this adjustment is greater than might have been anticipated, and is independent of the width of the lines. The principal advantage claimed for this method is that the accidental errors of measurement are reduced by reason of the double intervals measured. It is, in fact, almost equivalent to doubling the linear displacement of a plate without altering the width or definition of the lines. The method appears to be entirely free from large systematic errors which exist for most observers when they measure the displacements of the lines in an absorption spectrum with reference to the bright lines in a comparison spectrum.

The method cannot be used if there is asymmetry of the spectrum lines, for the reversal of the positive, right and left, brings the denser sides of the images together, and it is not possible to secure uniformity of illumination by any shifting of the positive plate. In such cases Mr. EVERSHED makes the positive copy by exposing *thru the glass* of the positive, and, in measuring, the positive is placed upon the ordinary negative in unreversed position. The dispersion effect is not doubled under these circumstances.

Various other photographic devices have been tried and found satisfactory. For example, two exposures of the original negative are made on an enlarged scale. One of these exposures is developed as an ordinary *positive,* and the other is treated chemically in the developing stage so as to appear as a *negative.* It has been found that the two *copies* may be measured with reference to each other, with extremely accurate results.

It is necessary that the slit of the spectrograph be adjusted to perfect perpendicularity to the length of the spectrum, which is easily done, and that the exposure of the original negative be timed to give correct intensity.

A number of possible objections to the method are mentioned by Mr. EVERSHED and shown to be insignificant, or at least no more serious than objections attaching to micrometric-wire methods of measurement.

Numerical examples are quoted. A spectrogram made for determining the rotation of the Sun was measured by the ordinary method and by the positive-on-negative method. The probable error of the mean result from the ordinary method was $\pm 0.012^{km}$ and from the positive-on-negative method $\pm 0.006^{km}$. For another spectrogram the probable errors were, old method, $\pm 0.016^{km}$, and new method, $\pm 0.006^{km}$. Fourteen plates for solar rotation had been measured to date, and in all of these the residuals are smaller by the new method, the average probable error being $\pm 0.015^{km}$ by the old method and $\pm 0.009^{km}$ by the new.

The settings upon well-defined lines in a comparison spectrum, such as that of iron, can also be made considerably more accurately by the new method than by the old.

The principles involved in EVERSHED's method resemble those of the HARTMANN spectro-comparator, but are capable of a much greater variety of applications. W. W. CAMPBELL.

ON AN AURORAL EXPEDITION TO BOSSEKOP IN THE SPRING OF 1913, BY CARL STÖRMER.[1]

This is a brief account of Professor STÖRMER's second expedition to Bossekop for the purpose of studying the aurora. The first one was undertaken in 1910, and the experience acquired on that occasion was very useful in planning the second one. The purposes of the expedition as set forth by the author were "to obtain more accurate, more numerous auroral photographs for the determination of the form of the aurora, and its height and situation in space, and, further, to experiment with objective-prism photographing and the taking of cinematograph films."

For the purpose of obtaining parallaxes simultaneous observations were made from two places about 27½ kilometers apart. The two stations were almost due north and south of each other. The observers had the use of the state telephone line between the stations, and in order to expedite intercommunication between them the switches and accessories were mounted on the observers themselves in such a manner as not to interfere with the free use of the arms. In this way it was found possible to make numerous simultaneous observations from the two stations, and, in all, data for 4,000 photographic determinations of parallax were secured.

Spectrum investigations seem to have been confined to the securing of photographs with the objective-prism. It is to be regretted that observations with a slit spectroscope were not undertaken so that accurate determinations of wave-length could be made.

The great number of photographs secured and the excellent quality of those reproduced to illustrate the article, attest the great value of the work of the expedition, the results of which will be worked up in detail for a later paper.

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[1] *Astrophysical Journal*, 38, 311, 1913.

W. H. WRIGHT.

NON-SELECTIVE TRANSMISSIBILITY OF RADIATION THROUGH DRY AND MOIST AIR, BY F. E. FOWLE.[1]

The data for this investigation were secured in the course of the measurement of the solar constant of radiation by the observers of the Smithsonian Astrophysical Observatory. Observation of the heat radiated by the Sun involves the determination, on each occasion, of the transparency of the atmosphere for rays of many different wave-lengths. On different days the amount of water-vapor varies, so that it is possible to set up an equation to allow for the effect of water-vapor on the transparency of the air, and to calculate the transparency of the dry air. The observations were made at Mt. Wilson and the values of the transparency discussed refer to the vertical column of air above that place.

The nature of the process of atmospheric absorption is one of great importance from many points of view. For instance, the validity of the method by which the effect of this absorption is allowed for in the investigation of the solar constant rests on the assumption that the absorption is "general," rather than "selective." Special interest, therefore, attaches to Mr. FOWLE's comparison of his observed values with those computed by the aid of the formulæ due to RAYLEIGH, SCHUSTER, and L. V. KING on the supposition that the dimming of rays, on passing thru the atmosphere, is produced by the molecular scattering of the air. The agreement between observation and theory is most striking, as will be seen from the following table:—

Wage-lengths (Ångstroms)—	3700	4000	4300	4600	5000	6000	7500	10,000	15,000
Transmission of column of dry air vertically above Mt. Wilson—									
Observed	0.683	.757	.808	.851	.885[1]	.916[1]	.977	.987	.990
Computed	0.680	.755	.808	.850	.890[1]	.946[1]	.977	.987	.986

The results marked (1) are in regions of known selective absorption and the discrepancies are of the right sign to be accounted for by this fact. In all the other cases the agreement between theory and observation is remarkable and leaves little doubt that the absorption of light above Mt. Wilson on a perfectly dry day is due, except in the limited regions just referred to, to molecular scattering of light. The observations covered the spectrum from 3400 A to 17000 A.

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[1] *Astrophysical Journal*, **38**, 392, 1913.

Assuming now that the theory of scattering is correct, the author has reversed the process and determined the number of molecules in a cubic centimeter under standard conditions of temperature and pressure. The result, 2.56×10^{19} is in close agreement with the best determination by other methods, 2.71×10^{19} (Millikan).

The effect of light scattering by molecules of water-vapor in the atmosphere is then taken up and is found to be much in excess of theory, the computed values being only one sixty-fourth of the observed ones. Several hypotheses are tentatively advanced to account for this great discordance. For details of these the original papers should be consulted.

In affording a pretty conclusive proof that the atmospheric absorption above Mt. Wilson is due practically entirely to molecular scattering of light, Mr. Fowle has also shown that the sky at that place is practically free from dust or other foreign material. Astronomers working under such favorable conditions are certainly to be congratulated.

W. H. Wright.

Preliminary Statistics of Nebulæ and Clusters.

The Observatory of Lund has taken up the work of statistical investigation of nebulæ and clusters—that is, statistics of their brightness, size, form, and distribution over the celestial sphere. A card catalog has been formed containing all the information obtainable concerning these objects. Most of this information has been taken from Dreyer's three catalogs, which are, the New General Catalog of 7,840 Nebulæ and Clusters, 1890; the Index of 1,529 Nebulæ, 1895; the Second Index of 3,857 Nebulæ, 1908. These catalogs are found in the *Memoirs of the Royal Astronomical Society*, Volumes 49, 51, 59. The three catalogs contain a total of 13,226 objects which are distinguished by five classes: clusters, globular clusters, planetary nebulæ, annular nebulæ, nebulæ.

During the further collection and study of material, the director, C. V. L. CHARLIER, has considered it advantageous to publish the immediate statistical results obtained from the three catalogs, but without discussion. These preliminary results are presented in fifty-two tables and eleven charts in pamphlet No. 15 of the Swedish Academy of Stockholm. Certain facts are self-evident, but other conclusions must be drawn with great caution. The main interest of these preliminary results lies in the distribution of the objects with respect to the Milky Way. The first table and charts give the distribution of the objects with respect to forty-eight squares of the celestial sphere. The table shows that there are 657 clusters, 112 globular clusters, 133 planetary nebulæ, 13 annular nebulæ, 12,308 nebulæ. The charts show that the clusters are congregated in the celestial polar regions and along the Milky Way, and that nebulæ are most numerous in galactic polar regions, altho numerous in the celestial polar regions.

In the second table, 11,486 of the nebulæ are divided into ten grades of brightness. A maximum number of 3,322 are designated as "very faint" and two thirds of them are designated "faint" or fainter than "faint." The charts show that the nebulæ are most numerous in the region of the north galactic pole, particularly the 1,700 brighter and the 500 brightest nebulæ.

In the third table, 10,498 of the nebulæ are divided into ten grades of size, and two thirds of them are "small" or smaller than "small"; that is, less than 30″ in diameter. The maximum number, 3,587, are designated "small." The charts again show that most of the seven thousand small nebulæ, and of the two thousand nebulæ of mean size, and of the eight hundred large nebulæ are collected round about the north galactic pole, altho many are found in the celestial polar regions.

In the fourth table, 8,469 of the nebulæ are divided into ten grades of form, including "round," "irregular," "extended." Again, two thirds are "round" and are quite evenly distributed among the four polar regions. Practically all of the 680 "irregular" nebulæ, however, are near the north galactic pole.

Further tables give the numerical relations between size and brightness for the stars in the separate squares of the sky, but not yet for the whole celestial sphere. Data upon condensation in the nebulæ are not yet analyzed. The relations between condensation and size, and form and brightness, and the directions of axes of symmetry in nebulæ are yet to be investigated.

The most obvious results of the investigation thus far are, first, that clusters and nebulæ incline to be antipodal classes of celestial objects, which is a well-known point; second, that the majority of nebulæ are "faint" and "small" and "round" and most numerous in the region of the north galactic pole.

G. F. Paddock.

The Red Stars.

A little piece of correlation regarding the variability of red stars is given by Mr. Backhouse of the West Hendon House Observatory in England, in the recent May number of the *Journal of the British Astronomical Association.* He was led to the matter by the question, Are all red stars variable? He has compiled a list of 118 stars which have been designated by observers as red or reddish, and has established ten grades of redness. These 118 stars are arranged in order of redness between the fourth and tenth grades. A summary gives the following results: All of the 12 very red stars between seventh and tenth grades are variables, while 10 of them are of spectral class N. Eighteen of the 19 quite red stars between sixth and seventh grades are variables, while 15 are of class N and one of class M. Fifteen of the 28 red stars between fifth and sixth grades are variables, while 12 are of class N and 10 of class M. Twenty of the 59 stars between fourth and fifth grades are variables, while 11 of them are of class N and 19 of class M and 16 of classes K and G. The percentage of variables in the four groups decreases as follows: 100, 95, 54, 34 per cent. All but one of the strongly red stars between sixth and tenth grades are variables and of class N. Nearly half, 48, of this list of red stars are of class N, and one quarter, 30, of class M. Eighty per cent of the class N stars and 50 per cent of class M are variables. While not all red stars are known to be variables, it appears that variability is related to spectral class and color.

G. F. Paddock.

GENERAL NOTES.

The toll of deaths among noted astronomers has been an exceedingly heavy one during the past few months.

Dr. SETH C. CHANDLER, for a long time editor of *The Astronomical Journal,* whose life and work during the past quarter century has been closely linked with astronomical progress in America, died on December 31, 1913, after a brief illness. A brief account of his work appears upon another page.

We regret also to record the death of Professor WINSLOW UPTON, on January 8, 1914. Professor UPTON was for thirty years head of the Department of Astronomy and Director of the Ladd Observatory of Brown University, and is well known to American astronomers and students through his "Star Atlas," and by his contributions to astronomical literature.

We note in *Nature* the announcement of the death of the Rev. EDMUND LEDGER, at the age of seventy-two. For thirty-three years he was professor of astronomy at Gresham College, London, and was the author of several popular works and articles on astronomical subjects.

Dr. JULIUS SCHEINER, Chief Observer at the Astrophysical Observatory of Potsdam, died on December 20, 1913, at the age of fifty-six. Among Dr. SCHEINER's many contributions to astrophysics, perhaps the most generally known is his "Stellar Spectroscopy." An account of his work will be given in our next number.

Dr. LADISLAS WEINEK, Director of the Observatory of Prague, died on the 12th of November, 1913, after a very short illness, at the age of sixty-six. Dr. WEINEK was a member of many scientific societies, and is perhaps best known for his publications in the field of lunar topography. The major part of Volume III of the *Publications of the Lick Observatory* is composed of the beautiful drawings of lunar formations made by Professor WEINEK from a study of negatives taken with the 36-inch refractor. As one example of the amount of careful and painstaking work which he employed in making these drawings, the beautiful plate of Copernicus alone necessitated no less than 224¾ hours of labor, distributed over 141 separate days.

Sir ROBERT BALL, Lowndean Professor of Astronomy at Cambridge, one of the most widely popular and well-known of modern astronomers, died on November 25, 1913. An account of his life is given by Mr. HECTOR MACPHERSON, JR., in the January number of *Popular Astronomy*, and from this article we quote the following extracts:—

> ROBERT STAWELL BALL was a native of Dublin, where he was born on July 1, 1840, and where his father, Dr. ROBERT BALL, was a well-known naturalist. . . . In early manhood he became devoted to astronomy, and in 1865 he received his first appointment—that of astronomer to the Earl of ROSSE at Birr Castle, Parsontown, Ireland, where he worked for two seasons. In 1874 he was made Royal Astronomer for Ireland, which carried with it the directorship of the Dunsink Observatory. In the same year he commenced his career as a public lecturer on astronomy, and in 1886 he received the order of knighthood . . . He continued as an active lecturer and author on astronomy till within a few years of his death, when he abandoned public lecturing, and practically retired from active work on account of failing health.
>
> Sir ROBERT BALL's services to astronomy were of two kinds. He was (i) an original investigator and (ii) a popular writer and lecturer. In both spheres he achieved distinction.
>
> (i) His original work was chiefly accomplished while he was Director of Dunsink Observatory and Royal Astronomer of Ireland. Here his main work was a search for stars with large parallaxes. . . . BALL was a mathematician of considerable power. For twenty-five years he grappled with the "Theory of Screws." The results of his investigations were summarized in memoirs communicated to the Royal Irish Academy from 1872 to 1897.
>
> (ii) In 1886 BALL's career as an independent investigator in astronomy came practically to an end. He published in that year "The Story of the Heavens," and commenced his career as a popular writer on the subject; . . . in the role of popular lecturer and writer he achieved distinction of no mean order.
>
> He was a prolific writer; among the works which appeared from his pen in rapid succession, the following may be named: "The Elements of Astronomy," "The Story of the Heavens," "Star Land," "Time and Tide," "In Starry Realms," "An Atlas of Astronomy," "In the High Heavens," "Great Astronomers," "A Primer of Astronomy," "The Earth's Beginning," "Spherical Astronomy."
>
> As a lecturer he visited the United States and Canada. In addition, he traveled practically all over the United Kingdom. It has been truly

said of him that "There is no important town in England, Scotland, Ireland, or Wales where Sir Robert Ball has not lectured and in most cases lectured often. At a very modest estimate, over one million people have heard him lecture."

It was his peculiar function, then, to impart to the amateur and to the unlearned listener the wonders and mysteries of astronomy; and he certainly succeeded in making his science popular. Thus his death is mourned by a wider circle than those of greater and less popular men. . . . He will long be remembered as the expounder of the science to the unlearned, and many an astronomer owes his first interest in his science to the popularizing work of the genial Irishman who has passed into the Great Beyond. Astronomy needs both its students and its popularisers. Science has a duty to the mass of mankind; and this duty some one must perform. In this sphere Sir Robert Ball nobly performed the task which he set himself."

Prizes Awarded by the French Academy of Sciences in December, 1913.—The Lalande prize was awarded to M. J. Bosler for researches on abrupt variations of terrestrial magnetism and their relation with disturbances appearing on the Sun; the Valz prize to Professor Alfred Fowler for his spectroscopic work, and, in particular, for his contributions to our knowledge of the origin of certain bands in the spectra of sun-spots, comet tails, and late-type stars; and the De Pontécoulant prize to M. K. Sundmann for his studies on the problem of three bodies.

In addition to these distinctly astronomical prizes, two of the general prizes offered by the Academy were this year awarded, the one to an astronomer, the other to physicists whose work has contributed directly to astronomical advance. The Wilde prize was awarded to M. A. Bonelly for his life work in astronomy; the Pierson-Perrin prize was divided, 2,000 francs each, being awarded to M. Ch. Fabry and M. H. Buisson for their precise determinations of the wave-lengths of spectral lines by means of the interferometer, and 1,000 francs to M. Rudolphe Soreau for a treatise entitled "L'Hélice Propulsive."

Among the grants made from the "Fonds Bonaparte," was one of 4,000 francs to M. Le Morvan for the publication of a photographic atlas of the Moon, and one of 2,000 francs to M. H. Abraham for the determination of velocity of propagation of Hertzian waves between Paris and Toulon. It is stated that in this latter research a new galvanometer, capable of recording the time of passage of a train of waves to 1-40,000 of a second, will be employed.

A New Observatory.—We learn from *The Observatory* for December that Mr. J. H. WORTHINGTON'S private observatory at Four Mark, near Alton, Hants, England, was formally opened on Saturday, November 8, 1913. The equipment includes a 10-inch Cooke refractor, a 20-inch reflector, and smaller instruments.

In the Oxford Notebook of the same issue of the *Observatory* it is pointed out that Trinity College, Cambridge, has furnished ten members of the staff of the Royal Observatory at Greenwich since its foundation; Jesus College, Cambridge, has furnished three, including the recently appointed chief assistant, Mr. H. S. JONES, and no other college more than one.

According to Bulletin 538 of the Harvard College Observatory, *Titan*, the brightest satellite of *Saturn*, has been found to be variable. This conclusion is based upon a discussion of the observations by the late O. C. WENDELL. Reduced to mean opposition distance, the light varies regularly from magnitude 8.53 to 8.77, the period coinciding with the time of revolution of the satellite.

It will be recalled that *Japetus*, the eighth satellite of *Saturn*, exhibits the same phenomenon, the range of brightness, however, being about 1.78 magnitude, from 10.40 to 12.18. As Professor PICKERING says, the explanation in both cases is probably that one side of the satellite is darker than the other.

The following note is taken from *Science* for November 28, 1913: "The new seven and one-half-inch photographic telescope was placed in position in the Memorial Observatory of the Nantucket Maria Mitchell Association on November 15th, the mounting and final adjustment by Alvan Clark & Son's Corporation completing the work. The lens was made by T. Cooke & Sons, York, England. It has been subjected to various tests at Harvard College Observatory by the Director, Dr. EDWARD C. PICKERING, personally, and by his several assistants who have given it careful attention. Rev. JOEL H. METCALF, whose astronomical discoveries by means of photographs are well known, has also carefully examined its work. By all of these it is pronounced good. The Nantucket Observatory is now well equipped for photographic study of asteroids or other heavenly bodies."

Miss MARGARET HARWOOD has been appointed to the Fellowship of the association for the year beginning June 15, 1914. This will be the third year of her service.

Readers who are specially interested in the progress of observations on *Mars* should not miss Professor W. H. PICKERING's "Monthly Reports on *Mars*," the first of which was published in *Popular Astronomy* for January, 1914.

The following French verses, quoted in a review in the *Bulletin* of the American Mathematical Society, may interest those who find difficulty in remembering the ratio of the circumference of a circle to its diameter. Count the letters in each word separately, and write the sums in order. They will give the ratio correct to thirty decimals—3.141592653589793-238462643383279:—

"Que j'aime à faire apprendre un nombre utile aux sages!
Immortel Archimède artiste ingénieur
Qui de ton jugement peut priser la valeur!
Pour moi ton problème eut de pareils avantages."

The American Association for the Advancement of Science held its sixty-fifth meeting at Atlanta, Georgia, from December 29, 1913, to January 3, 1914. Professor E. C. PICKERING, the retiring president, delivered the annual address, taking for his subject "The Study of the Stars." The address is printed in full in *Science* for January 2, 1914.

The Astronomical and Astrophysical Society of America met at the same place and time, several of its sessions being joint sessions with Section A of the Association.

Mr. E. W. MAUNDER, for many years superintendent of the Solar Department of the Royal Observatory at Greenwich, retired on November 6, 1913, in accordance with the regulations, having completed forty years of service in the institution. In addition to his technical papers, Mr. MAUNDER has written many articles and books of interest to the general reader, one of the most recent being his volume discussing the problem of "Life on Other Worlds." The *Observatory* recalls attention to the fact that he was also the founder of the British Astronomical Association.

Just as this number of the *Publications* is going to press we learn from press dispatches the news of the death of Sir DAVID GILL, and are compelled to add one more name to the already too long list of great astronomers who have recently passed away.

Sir DAVID GILL was nearly seventy-one years of age, and for nearly forty years had been a commanding figure in the astronomical world. The list of his published papers and the various astronomical and geodetic investigations which he inaugurated and carried thru would in itself be a long one. He will doubtless be longest remembered for his long and valuable services, both as an investigator and as an executive while in charge of the Observatory of the Cape of Good Hope.

He was a member of many learned societies, and the recipient of many honors and medals; our members will recall that he was the third to be awarded the Bruce Gold Medal of the Astronomical Society of the Pacific.

He retired from active duties in 1907, but continued to manifest almost until the day of his death the same keen and vivid interest and the same wise counsel and sane judgment in astronomical problems.

ADDENDUM TO THE MINUTES OF THE SPECIAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON NOVEMBER 29, 1913, TO CONSIDER THE AWARD OF THE BRUCE GOLD MEDAL FOR THE YEAR 1914.

There were present Vice-President R. G. AITKEN and Directors CUSHING, CRAWFORD, TOWNLEY, COSTA, CORNISH, MARKWART, and RICHARDSON.

The proxy of Director GEO. E. HALE was held by Vice-President AITKEN.

Nominations, in accordance with the statutes for the bestowal of the Bruce Medal, were received from the Directors of the observatories of Harvard, Lick, Yerkes, Greenwich, and Paris. Berlin did not exercise its prerogative to nominate.

After full discussion of the merits and endorsements of the various nominees, a ballot was taken, which resulted in the unanimous selection of Dr. O. BACKLUND, Director of the Royal Observatory of Pulkowa, Russia, as the Bruce Medalist for 1914.

The assenting vote of record was as follows: AITKEN, HALE, CORNISH, CRAWFORD, COSTA, MARKWART, TOWNLEY, and RICHARDSON.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY ON JANUARY 31, 1914, AT 7:30 P. M.

There were present Directors CRAWFORD, CUSHING, CORNISH, MARKWART, and RICHARDSON. CRAWFORD presided.

Communications were read by the Secretary from Professor J. N. BOWMAN and S. L. BOOTHROYD, of the University of Washington, inviting the Society to meet in Seattle in May, 1914, at the time of the sessions, in that city, of the Pacific Association of Scientific Societies.

After some discussion, it was decided that conditions were not favorable at present for such action, and the Secretary was instructed to so inform Messrs. BOWMAN and BOOTHROYD.

A communication was read from the Secretary of the Sociedad Astronomica de Barcelona, Spain, asking an exchange of publications. It was so ordered.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ASSEMBLY HALL OF THE PHELAN BUILDING, SAN FRANCISCO, ON JANUARY 31, 1914, AT 8:00 P. M.

In the absence of both President McAdie and First Vice-President Aitken, the meeting was called to order by Director R. T. Crawford.

The minutes of the last annual meeting were approved as printed in the *Publications.*

Under the head of Reports of Committees, reports were received and approved as follows:—

From C. S. Cushing, Chairman of the Finance and Auditing Committee, stating that the books and accounts of the Treasurer had been examined and found correct.

From D. S. Richardson, Chairman of the Library Committee, stating that sixty volumes had been added to the library during the past year.

From the Donohoe Comet-Medal Committee as follows:—

Six comets were discovered in the year 1913, as follows:—

Comet *a* 1913, an unexpected comet discovered by Monsieur A. Schaumasse at the Nice Observatory, May 6, 1913.

Comet *b* 1913, an unexpected comet discovered by Reverend J. H. Metcalf, at Taunton, Massachusetts, September 1, 1913.

Comet *c* 1913, an unexpected comet discovered by Monsieur G. Neujmin at Simeis, Russia, September 3, 1913.

Comet *d* 1913, Westphal's periodic comet, detected on its return by Mr. P. T. Delavan at the National Observatory, La Plata, Argentina, September 26, 1913.

Comet *e* 1913, Giacobin's periodic comet, detected on its return by Herr E. Zinner at Bamburg, Germany, October 23, 1913.

Comet *f* 1913, an unexpected comet discovered by Mr. P. T. Delavan at the National Observatory, La Plata, Argentina, December 17, 1913.

In accordance with the statutes of the Society, the Donohoe Comet-Medal has been awarded to Messrs. Schaumasse, Metcalf, Neujmin, and Delavan for the discoveries of comets *a*, *b*, *c* and *f*, respectively.

W. W. Campbell,
Heber D. Curtis,
Sidney D. Townley,
Comet-Medal Committee.

(EIGHTY-FIRST) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Mr. P. T. Delavan, of La Plata, Argentina, for the discovery of an unexpected comet on December 17, 1913

Committee on the Comet-Medal:
W. W. Campbell,
Heber D. Curtis,
Sidney D. Townley.

The report of the Treasurer, printed elsewhere, was then submitted.

The next business in order was the election of a Board of Directors and a Publication Committee for the ensuing year. The Nominating Committee, of which Mr. Beverly L. Hodghead was Chairman, submitted the following ticket to the consideration of the Society:—

For Directors—A. B. Baird, R. G. Aitken, W. H. Crocker, Charles Burckhalter, C. S. Cushing, R. T. Crawford, J. Costa, S. D. Townley, F. V. Cornish, A. H. Markwart, and D. S. Richardson.

For Publication Committee—R. G. Aitken and H. D. Curtis.

Nominations were ordered closed.

Mr. Ziel was appointed teller and ballots were distributed, with the announcement by the Chair that the polls would remain open until 9 o'clock.

A verbal report was then made by the Chair upon the action of the Board of Directors at the special meeting of November 29, 1913, to consider the award of the Bruce Gold Medal for the year 1914. He stated that the award had been made upon the unanimous choice of nine Directors to Professor O. Backlund, Director of the Royal Observatory of Pulkowa, Russia.

Letters were then read by the Secretary from the Society to Professor Backlund proffering the medal, and the very gracious reply of the latter accepting the honor and expressing his appreciation.

Mr. Ziel reported that the medal had been ordered from Paris and should be received in San Francisco sometime within a month.

The next business in order was the reading, by Dr. Crawford, of the address of the retiring President, Professor A. G. McAdie. This address, which is a worthy tribute to the character and life work of Professor O. Backlund, the Bruce Medalist, is printed elsewhere in this issue.

The reading was followed by a very remarkable verbal address by Dr. A. O. Leuschner, Director of the Students' Observatory of the University of California, upon "The Work of the Students' Observatory in Orbit Computation." It was remarkable in that it attempted, successfully, to explain in popular terms a very difficult subject; which is to say, that it was so presented as to convey to the humble layman in the field of science some conception of the mighty problems involved in orbit computations. A vote of thanks was tendered to Dr. Leuschner by the meeting.

Before the close of Dr. Leuschner's address, the ballots were collected and counted. Eleven ballots were cast, the result being unanimously in favor of the eleven Directors and two members of the Publication Committee above noted. They were thereupon declared by the Chair to be duly elected for the ensuing year.

The meeting then adjourned.

D. S. Richardson,
Secretary.

MEETING OF THE NEWLY ELECTED BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, 752 PHELAN BUILDING, SAN FRANCISCO, ON JANUARY 31, 1914, AT 10:00 P. M.

There were present Directors CRAWFORD, CUSHING, BAIRD, CORNISH, BURCKHALTER, and RICHARDSON.

The Board proceeded to organize by electing the following officers, all of whom were unanimously elected:—

For President—R. T. CRAWFORD.
For First Vice-President—R. G. AITKEN.
For Second Vice-President—S. D. TOWNLEY.
For Third Vice-President—C. S. CUSHING.
For Secretary and Treasurer—D. S. RICHARDSON.
For Secretary on Mt. Hamilton—R. G. AITKEN.
For Donohoe Comet-Medal Committee—W. W. CAMPBELL, R. H. TUCKER, *and* S. D. TOWNLEY.
For Library Committee—D. S. RICHARDSON, F. V. CORNISH, and A. H. MARKWART.

The President appointed the following members to serve on the Finance Committee: C. S. CUSHING, WM. H. CROCKER, and A. H. MARKWART.

A motion was made, seconded and unanimously carried, instructing the President and Secretary to prepare a suitable letter of condolence for transmital to the family of the late Sir DAVID GILL, and to the Royal Astronomical Society of England, expressive of the respect in which that distinguished scientist was held by the Astronomical Society of the Pacific, of which he was Bruce Medalist for 1900.

Adjourned.

D. S. RICHARDSON,
Secretary.

REPORT OF THE TREASURER OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC FOR THE FISCAL YEAR ENDING JANUARY 31, 1914.

Dr. GENERAL STATEMENT.

Balances January 31, 1914:	
Alvord Fund	$5,021 83
Library Fund	3,713 99
Dolbeer Fund	5,010 00
Comet-Medal Fund	887 99
Bruce Medal Fund	2,977 29
Life Membership Fund	2,067 28
General Fund	578 63
	$20,257 01
Less Bond Depreciations written off	85 75
Balance January 31, 1914	$20,171 26

Cr.

By seventeen bonds	$17,154 69
Cash in banks	3,016 57
	$20,171 26

STATEMENT BY FUND.

William Alvord Fund.

Dr.

To Balance January 25, 1913	$5,000 00	
½ Los Angeles Gas	497 50	
1 Moulton	1,000 00	
1 Blue Lakes	1,001 25	
Interests	256 93	
Cash, 2 Sunset bonds	2,100 00	$9,855 68

Cr.

By Bonds purchased (2½)	$2,498 75	
Commission and Interest on same	25 56	
2 Sunsets called	2,168 06	
Transfer to General Fund	141 48	4,833 85
Balance January 31, 1914		$5,021 83
Written off		66 71
Balance		$4,955 12

Libary Fund.

Dr.

To Balance January 25, 1913	$3,772 80	
½ Los Angeles Gas	497 50	
1 Blue Lakes	1,001 25	
Cash, 1 Sunset	1,050 00	
Interests	187 68	$6,509 23

Cr.

By Bonds purchased (1½)	$1,498 75	
1 Sunset called	1,084 02	
Commission and Interest	22 47	
Transfer to General Fund	180 00	
Maddrill	10 00	2,795 24
Balance January 31, 1914		$3,713 99
Written off		1 26
Balance		$3,712 73

Dolbeer Fund.

Dr.

To Balance January 25, 1913	$5,000 00	
½ Los Angeles Gas	497 50	
Interests	235 12	$5,732 62

Cr.

By ½ Bond purchased	$ 497 50	
Commission and Interest	3 54	
Transfer to General Fund	221 58	722 62
Balance January 31, 1914		$5,010 00
Written off		14 80
Balance		$4,995 20

COMET-MEDAL FUND.

Dr.

To Balance January 25, 1913		$ 853 53
Interests		34 46
Balance January 31, 1914		$ 887 99

BRUCE MEDAL FUND.

Dr.

To Balance January 25, 1913	$2,934 20	
½ Los Angeles Gas	497 50	
Interests	146 63	$3,578 33

Cr.

By ½ Bond purchased	$ 497 50	
Commission and Interest	3 54	
Medal for 1914	100 00	601 04
Balance January 31, 1914		$2,977 29
Written off		1 26
Balance		$2,976 03

LIFE MEMBERSHIP.

Dr.

To Balance January 25, 1913	$1,974 36	
1 Los Angeles Gas	996 25	
2 Memberships	100 00	
Interests	95 09	$3,165 70

Cr.

By 1 Bond purchased	$ 996 25	
Commission and Interest	7 08	
Transfers to General Fund	95 09	$1,098 42
Balance January 31, 1914		$2,067 28
Written off		1 72
Balance		$2,065 56

GENERAL FUND.

Dr.

To Balance January 25, 1913	$ 682 74	
Dues	663 10	
Sale of *Publications*	42 07	
Insurance refunded	90	
Dolbeer Fund	221 58	
Library Fund	1,239 74	
Alvord Fund	2,290 96	
Life Fund	95 09	$5,236 18

Cr.

By Library Fund	$1,049 74	
Alvord Fund	2,149 48	
Blair Murdock, printing	858 90	
Rents	242 50	
Salaries	240 00	
Postage	35 00	
Insurance	7 50	
Expenses Bruce Medal	3 55	
Taxes	20 18	

Maddrill, Monthly Notices	$ 10 00	
Crocker safe-deposit box	4 00	
Keys	1 50	
Sunset Publishing House	4 00	
Cartage	4 75	
Dues, Pacific Association S. S.	5 00	
Engraving Comet-Medals	4 20	
Lantern	10 00	
Incidentals	7 25	
Total		$4,657 55
Balance January 31, 1914		$ 578 63

Respectfully submitted,
D. S. Richardson,
Secretary and Treasurer.

January 31, 1914.

We hereby certify that we have examined the foregoing account and have found the same to be correct.

Charles S. Cushing,
Frank V. Cornish,
B. A. Baird,
Auditing Committee.

FUNDS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD IN DEPOSIT BY THE MERCANTILE TRUST COMPANY OF SAN FRANCISCO, AT 464 CALIFORNIA STREET.

These securities are all of the face denominations of $1,000, and the values given represent their original cost to the Society.

Life Membership Fund.

One South Pacific Coast Railroad Company's 1st mortgage, guaranteed 4 per cent Gold Bond, No. 3406. Principal due July, 1937; interest payable in January and July	$1,000 00
One Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 712. Principal due July 1, 1934; interest payable January 1st and July 1st	996 25

Alexander Montgomery Library Fund.

One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4328. Principal due July, 1932; interest payable January and July	1,040 00
One Contra Costa Water Company's 5 per cent Gold Bond, No. 1665. Principal due January, 1915; interest payable January and July..	1,035 00
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 714. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 380. Principal due 1938; interest payable March 15th and September 15th	1,001 25

Bruce Medal Fund.	
One Bay Counties Power Company 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1636. Principal due September, 1930; interest payable March and September	$ 1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6836. Principal due September, 1922; interest payable in March and September........	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 714. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
John Dolbeer Fund.	
One South Pacific Coast Railway Company's 1st mortgage 4 per cent guaranteed Gold Bond, No. 3407. Principal due July, 1937; interest payable in January and July	1,000 00
One Oakland Transit consolidated 1st consolidated mortgage 5 per cent Gold Bond, No. 4329. Principal due July, 1932; interest payable January and July	1,040 00
One Bay Counties Power Company's 1st consolidated mortgage 5 per cent sinking fund Gold Bond, No. 1637. Principal due September, 1930; interest payable in March and September	1,012 50
One Edison Electric Company, Los Angeles, 1st and refunding mortgage 5 per cent Gold Bond, No. 6837. Principal due September, 1922; interest payable March and September	977 22
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 713. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
William Alvord Fund.	
Two Contra Costa Water Company's 5 per cent Gold Bonds, Nos. 87 and 1666. Principal due January, 1915; interest payable in January and July	2,071 50
One-half Los Angeles Gas and Electric general mortgage 5 per cent Gold Bond, No. 713. Principal due January 1, 1934; interest payable January 1st and July 1st	497 50
One Blue Lakes Water Company 6 per cent 1st mortgage Gold Bond, No. 381. Principal due 1938; interest payable March 15th and September 15th	1,001 25
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EDWARD SINGLETON HOLDEN, Sc.D., LL.D., LITT.D.

By W. W. CAMPBELL.

Professor EDWARD SINGLETON HOLDEN, first Director of the Lick Observatory, died at the U. S. Military Academy, West Point, N. Y., on March 16, 1914.[1]

Professor HOLDEN was born in St. Louis, Missouri, on November 5, 1846. He was graduated from Washington University, St. Louis, receiving the A. B. degree in 1866. He was presumably a student in that institution during the years 1862-66. WILLIAM CHAUVENET, author of the well-known *Manual of Spherical and Practical Astronomy*, was Chancellor of, and Professor of Mathematics and Astronomy in, Washington University during that period. It is probable that Mr. HOLDEN pursued astronomical studies more or less extensive with Professor CHAUVENET. In this connection, it is of interest to note that Mr. HOLDEN married Professor CHAUVENET'S daughter MARY in the year 1871. Those of Professor HOLDEN'S later associates who are now residing on Mount Hamilton do not remember that he referred specifically to having studied astronomy in St. Louis, but he did remark frequently that his interest in astronomical subjects had been aroused on the occasions of visits to Harvard College Observatory while his cousin, Professor GEORGE P. BOND, was director of that institution (1859-65). There are reasons for concluding that Professor HOLDEN'S equipment for astronomical pursuits was largely self-acquired, thanks to his wonderful power of absorbing knowledge, and that it came only in minor degree from formal studies of astronomy in the class room.

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[1] Professor HOLDEN underwent a surgical operation two years ago for an abscess in his side. From this he never fully recovered, tho he attended to his library duties until three weeks before his death. He was buried with military honors at West Point.

During the years 1866-1870 Mr. HOLDEN was a cadet in the U. S. Military Academy at West Point, graduating in the latter year. He ranked third in his class. During the academic year 1870-71 he was Second Lieutenant in the Fourth U. S. Artillery. In the following year he was Second Lieutenant in the U. S. Corps of Engineers, serving as Instructor in Natural Philosophy in the Military Academy, and during the year 1872-73 he was Instructor of Practical Military Engineering in the Academy. In 1872 he published an octavo treatise on *The Bastion System of Fortifications, Its Defects and Their Remedies.*

In March, 1873, Mr. HOLDEN resigned his commission in the army to accept appointment as Professor of Mathematics in the U. S. Navy, for service as astronomer in the U. S. Naval Observatory at Washington. In the Naval Observatory, Professor HOLDEN came immediately into close professional relations with SIMON NEWCOMB, serving as assistant to NEWCOMB in the work of the just-completed 26-inch Clark equatorial telescope. It is clear from historical developments, as well as from passages in NEWCOMB's *The Reminiscences of an Astronomer,* that NEWCOMB was tremendously impressed with HOLDEN's energy and ability. When Mr. D. O. MILLS, President of JAMES LICK's first Board of Trustees, went to Washington in 1874 to consult with NEWCOMB concerning plans for the Lick Observatory, NEWCOMB "suggested that a director of the new establishment should be chosen in advance of beginning active work, so that everything should be done under his supervision. As such director I suggested that very likely Professor HOLDEN, then my assistant on the great equatorial, might be well qualified. . . . The necessity of choosing a director was not, however, evident, but communication was opened with Professor HOLDEN as well as myself to an extent that I did not become aware of until long afterward."[1]

It is an illuminating comment upon Professor HOLDEN's promise as an astronomer of the future that he should be recommended, and probably tentatively selected, as the director of the proposed Lick Observatory, to contain the largest and most powerful telescope in existence, at a time when his astronomical experience had covered but little more than one year. Professor HOLDEN was then less than twenty-eight years of age. The appointment referred to was not made, as the First Board of Trustees resigned in 1875, following certain unsatisfactory relations with JAMES LICK, and a new board of entirely different personnel was appointed by LICK in 1875. Captain RICHARD S. FLOYD was president of the Second Board of Trustees, as well as of the Third Board, appointed in 1876, under whose auspices the actual construction of the observatory was conducted.

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[1] NEWCOMB's *Reminiscences,* page 184.

Professor HOLDEN was sent to London in 1876 as a delegate from the United States Government to examine and report upon the South Kensington Loan Collection of Scientific Instruments, especially as to improvements in astronomical and geodetical instruments. While engaged in this service he met Captain FLOYD, and the plans for the Lick Observatory, proposed by Professors NEWCOMB and HOLDEN in 1874, were thoroly discussed. From that time forward Professor HOLDEN was freely consulted, as was Professor NEWCOMB, in the making of plans for buildings and instruments and as to the correspondence with astronomers, opticians, and instrument-makers.

While on the staff of the Naval Observatory, Professor HOLDEN made himself very familiar with the literature of astronomy; he prepared and published index catalogs of books and memoirs relating to nebulæ and star clusters, to the transits of *Mercury*, and to other subjects; he observed comets, nebulæ, satellites, double stars, etc.; he interested himself especially in the nebula of *Orion*, publishing historical notes and his own observations as a *Monograph of the Central Parts of the Nebula of Orion* (1882); he prepared annual reports on the progress of astronomy; he made contributions of value to librarians; he prepared and published a volume on *Sir William Herschel: His Life and Works* (1881); in collaboration with Professor C. S. HASTINGS, he prepared a *Synopsis of the Scientific Writings of Sir William Herschel* (1881); he published an investigation of the objective and micrometers of the

26-inch equatorial (1881); he wrote many popular articles for the magazines, and many semi-popular articles for scientific journals; and in collaboration with Professor NEWCOMB he wrote a textbook on astronomy (1880).

Professor HOLDEN was in charge of a small expedition dispatched by the Naval Observatory to Central City, Colorado, to observe the total solar eclipse of July 29, 1878. Of his party Professor C. S. HASTINGS was an official member and Mr. JAMES E. KEELER a volunteer member. The sky was clear, but Professor HOLDEN'S visual observations in search of the hypothetical planet *Vulcan* failed to disclose any unidentified objects.

In 1881 Professor HOLDEN resigned his commission in the navy and accepted the directorship of the Washburn Observatory, University of Wisconsin, in succession to Professor JAMES C. WATSON, deceased. This position he held during the years 1881-85. He visited Mount Hamilton in 1881 to assist in the installation of the meridian circle, and to observe the transit of *Mercury*. He also visited Mount Hamilton in the fall of 1883 on the return trip of the eclipse expedition of that year to the South Seas. At Madison he organized and pushed the observational duties of the Washburn Observatory with vigor. He discovered and listed many red stars; he discovered a considerable number of double stars; he observed the 303 stars of AUWERS'S fundamental catalog with the meridian circle; he observed the bright comet of 1882 and other comets of lesser interest; he observed the transit of *Venus* in 1883; he was interested in studies of HERSCHEL'S Star Gauges, and collected statistics of stellar distribution from the charts of PETERS, WATSON, CHACORNAC and PALISA; and he made measures of the ring system of *Saturn*. In company with Professor HAGEN, he prepared and published a catalog of 1001 southern stars on the basis of TACCHINI'S observations.

In harmony with his policy of providing opportunities for other astronomers, he invited Professor BURNHAM to make frequent and systematic use of the 15-inch Clark refracting telescope of the Washburn Observatory; and with this telescope BURNHAM discovered many double stars and observed a still greater number.

The National Academy of Sciences organized an expedition to observe the total solar eclipse of May 6, 1883, from the Caroline Islands. Appropriations in support of the expedition were made by Congress and from the Watson Fund of the National Academy. Professor HOLDEN was appointed chief of the party and scientific director of the expedition. Associated with him were four young astronomers whose names later became well known: Professor C. S. HASTINGS of Johns Hopkins University, Mr. E. D. PRESTON, Mr. S. J. BROWN and Mr. WINSLOW UPTON. The Caroline Islands, consisting of a few very small coral islands lying close together, are situated about one hundred and seventy-five miles northeast of Flint Island, where the Crocker expedition from the Lick Observatory, University of California, observed the eclipse of January 3, 1908. It was a serious question in Professor HOLDEN's mind whether the expedition of 1883 should locate on the Caroline Islands or on Flint Island. A French expedition under Monsieur JANSSEN reached the Caroline Islands a few days after the landing of the American party.

The experiences passed thru by many eclipse observers in the tropics fell to the lot of the observers in 1883: the sky was clear during the greater part but not all of totality, and during the partial phases there were clouds in abundance and some rain. The air in most tropical localities is so near the saturation point that the fall of temperature when the Moon is covering the Sun is sufficient to cause clouds and precipitation; and that the sky is clear one minute does not mean that the following minute may not bring clouds and the following five minutes rain.

Professor HOLDEN's expedition was successful in carrying out all the main features of the program. A visual search for the hypothetical planet *Vulcan* led to negative results. Spectroscopic and polariscopic observations of the corona were secured as planned. The details of the corona were observed visually. The times of contacts were estimated and the influence of the eclipse upon the meteorological elements was observed. The memoir on the eclipse of 1883 is a model in form, and is frequently referred to by past and prospective observers of eclipses.

In 1885 Professor HOLDEN was appointed President of the University of California and Director of the Lick Observatory, to serve in the former capacity until the observatory should be completed, and thereafter in the latter capacity. His services as President terminated with June 1, 1888, and on this date he assumed the active directorship of the Lick Observatory. During the last three years of the construction period he was very intimately associated with the Lick trustees as adviser. It was upon his advice and recommendation that Mr. JAMES E. KEELER, assistant to Professor LANGLEY, came to Mount Hamilton in 1886 to assist the trustees with the installation of the instruments, and with the understanding that he would become a member of the permanent staff, in charge of the department of spectroscopy.

Professor HOLDEN's term of office as the first Director of the Lick Observatory terminated by resignation on December 31, 1897.

An astronomer has said that "the first requisite for the director of a great observatory is to have a very clear notion of just what kind of work ought to be done, how it should be done, and then to give all the aid in his power to the investigator." Director HOLDEN selected the most promising men he could find in the United States to comprise the observatory staff. He assigned them definitely to lines of research which the future has shown to be of the highest importance. He gave them such opportunities to succeed as no other astronomer had ever enjoyed. In particular, he gave them great liberty of action and wished them success. The comments in the last two sentences are made in general terms, but they are also a reflection of my appreciation of the opportunities which came to me through Professor HOLDEN's office. To quote from NEWCOMB's *Reminiscences*, page 190:

> "The institution make its mark almost from the beginning. I know of no example in the world in which young men, most of whom were beginners, attained such success as did those whom HOLDEN collected around him."

The evidences of Professor HOLDEN's organizing ability and energy are written all over the Lick Observatory. Nor were these qualities confined narrowly to the internal work of the institution. The total solar eclopse of January 1, 1889, was effectively studied, on his initiative, by a well-equipped expedition from the Lick Observatory. The Astronomical Society of the Pacific is truly his creation. The Montgomery Library Fund of the Society, the Donohoe Comet-Medal Fund and the Bruce Gold Medal Fund were provided at his solicitation. He devised the unique regulations governing the bestowal of the Bruce Gold Medal, which ensure that the award made by the trustees of the Society shall be of unquestioned wisdom. In maintaining the relations of this observatory with other similar institutions thruout the world and in making the more important results of the Observatory's researches known to the scientific public Professor HOLDEN gave devoted and able effort.

His own scientific work in the Lick Observatory related principally to the photography of the Moon. He encouraged the study of his lunar photographs by astronomers in other institutions, and he published a lunar atlas comprising nineteen large sheets, the reproductions of enlarged photographs. He made occasional observations of the nebulæ and of the planets. His extensive administration duties did not leave him much time for personal research.

The last years of Professor HOLDEN's administration were marred by the existence of animosities in the observatory community, and by much ill-advised criticism in the newspapers. The time has not come for any member of the staff under Professor HOLDEN's administration to attempt a critical analysis of the situation, and I shall let a distinguished non-partisan speak. To quote again from NEWCOMB's *Reminiscences*, pages 192-193:

> "The term of HOLDEN's administration extended through some ten years. To me its most singular feature was the constantly growing unpopularity of the director. I call it singular because, if we confine ourselves to the record, it would be difficult to assign any obvious reason for it. One fact is indisputable, and that is the wonderful success of the Director in selecting young men who were to make the institution famous by their abilities and industry. If the highest problem of administration is to select the right men, the new director certainly mastered it. So far as liberty of research and publication went, the administration had the appearance of being liberal in the extreme. Doubtless there was another side to the question."

It is my duty to remove two erroneous impressions, so far as I here have the power. Many astronomers in the Eastern States, and a few in Europe, have been imbued with the belief that Director HOLDEN's growing unpopularity with his staff was occasioned in part at least by his desire to withhold from them the credit for their scientific work, and also by certain shortcomings in his private life on the mountain. How these widely prevailing views originated and spread I do not know. In my opinion they were absolutely without basis in fact: his extension of credits to colleagues and assistants was generous; and as far as I have ever heard any member of the observatory community speak, his private life amongst us was exemplary.

Professor HOLDEN's astronomical career practically terminated with his departure from Mount Hamilton in October, 1897. He resided in New York City until the latter part of 1901, where much of his time was devoted to the writing of popular articles and books on astronomical subjects of every-day interest.

From November, 1901, until his death he was Librarian of the United States Military Academy. When his former associates heard of this appointment they said without hesitation: "He will be wonderfully successful"; and so it seems he was. In 1907 the well-known journal, *Army and Navy Life,* inaugurated a series of biographies of *Distinguished Graduates of the U. S. Military Academy in Civil Life,* by beginning "this series of articles with a brief survey of the distinguished career of the Academy's most learned living alumnus, Dr. EDWARD SINGLETON HOLDEN," prepared by Captain E. G. DAVIS, U. S. A. I shall let Professor HOLDEN's biographer speak of his services to the library of the Military Academy:—

> " . . . He has labored unceasingly, within the means at his command, to make the library meet the legitimate needs of every instructor and every cadet.
>
> "He saw from the first the magnitude of this last great task which he has undertaken. He found the library fairly well supplied with books on every subject, but their contents were not readily available. His first task was to complete the collection so that every subject is now represented by the standard books that give its past history, as well as by the current periodicals which exhibit its present progress. Some 30,000 volumes have been added to the library since 1901, . . .

"All the new books of the library and all the military books, whether new or old, have been thoroughly catalogued and made available to instructors and others. A veritable mine of information has been opened for them in which they can find unlimited material for the extension of their professional studies or for original research in any field.

"Every nook and cranny of the library has been ransacked and Dr. HOLDEN has personally examined every paper in the records of the bureaus of the War Department from the beginning of 1838 (the date of the fire which destroyed the records at West Point), making copies of all the important Mss. So that now for the first time since 1838 the historical records at West Point are substantially complete. Many orderly books, etc., have been acquired by gift or purchase.

"All of this material has been catalogued and much of it has been thoroughly gone over, either by Dr. HOLDEN himself or, under his direction, by officers who have voluntarily assisted him in this work. . . .

"His report as librarian for the last year shows that about twenty-five per cent of the younger officers did volunteer work for the library and that more than one-third of the officers of the post were there engaged in serious work and many more at their own quarters. . . .

"Recently an officer, who was to deliver a lecture to the student officers at a nearby post, wrote to Dr. HOLDEN asking for assistance in the collection of historical data concerning the development of a particular military subject.

" 'Visit the library,' replied the doctor, 'and all our books and manuscripts relating to this subject will be placed at your disposal.'

"The officer came. He found a table piled high with books and papers, containing, perhaps, every treatment of the subject from the time of the Greeks and Romans down to the present. He was inclined to despair when he saw the mass of material before him. To wade through such a pile of books seemed an endless task. But to his astonishment he found that the work had been more than half done for him; he was furnished with a manuscript bibliography of his subject, which gave him in a moment just what the various books contained and told him where to look for it. He went away delighted and enthusiastic. Dr. HOLDEN has prepared similar complete bibliographies on every military subject. As soon as funds are available they are to be printed and distributed to the service. When this is done officers will know just what data is available for the study of any military subject in which they may be interested."

Professor HOLDEN'S interests took a wide range. He has written and published on the bastion system of fortifications; on the number of words used in speaking and writing; on the celebrated cipher dispatches of 1876, relating to the election of a President of the United States in that year; on the treatment of pamphlets in special libraries; on studies in Central American picture writing; on a system of local warnings against tornadoes; on *The Mogul Emperors of Hindustan,* a delightful volume published in 1895; on *Mountain Observatories* (1896): on *Memorials of W. C. and G. P. Bond* (1897); on *Pacific Coast Earthquakes* (1898); a *Primer of Heraldry* (1898); a volume on the *Family of the Sun* (1899); *Real Things in Nature* (1903); *The Sciences* (1903); the *Centennial History of the U. S. Military Academy,* 1802-1902, Vol. II, containing a full bibliography of West Point for 1524-1902, of the Military Academy for 1776-1902, and of the writings of all graduates of the Military Academy during 1802-1902. There are many magazine articles on still other subjects.

Distinguished honors were bestowed upon Professor HOLDEN. He was elected Foreign Associate of the Royal Astronomical Society in 1884; a member of the National Academy of Sciences in 1885; and later to membership in the Astronomical Society of France, in the Italian Spectroscopic Society, in the American Academy of Arts and Sciences, etc. He received the degree of LL.D. from the University of Wisconsin in 1886, and from Columbia University in 1887; the degree of Sc.D. from the University of the Pacific in 1896; and the degree of Litt.D. from Fordham College in 1910. He served as a member of the Board of Visitors to the U. S. Military Academy in 1885, and of the Board of Visitors to the U. S. Naval Academy in 1896. The reports of the Boards of Visitors for those years were live documents. He was made a Knight Commander of the Ernestine Order of Saxony in 1894, and a Knight of the Royal Order of the Dannebrog in 1895; and the Order of Bolivar was conferred upon him in 1896.

Professor HOLDEN possessed abilities wonderful in many ways. His knowledge of literature, both general and scientific, including, of course, the literature of astronomy, was very extensive, and this knowledge appeared always to be at his immediate command. He enjoyed writing, he wrote rapidly and with a fine literary style. It is a remarkable fact that the heavy correspondence of the Lick Observatory was conducted by Professor HOLDEN's personal pen thruout his term of office. He did not utilize the services of a stenographer, and only an occasional letter was copied with the typewriter. His social abilities were of very high order. His conversation was entertaining to the point of brilliancy. His hearers did not always agree with his point of view, which he defended with vigor and skill, but no one could be found to deny that Professor HOLDEN had made the subject seem alive. His lamented death puts former associates into the reminiscent mood which accompanies the passing of a remarkably interesting man.

HISTORICAL QUOTATIONS.

By W. W. CAMPBELL.

A recent reading of early contributions to astronomical literature has brought me upon many interesting passages which have not been used by the principal historians of astronomy, tho I since fine that some of these passages are referred to by an occasional modern writer. I venture to quote on two subjects:

(a) The idea that the Milky Way is composed of vast numbers of separate stars goes back at least to Democritus (450 ± B. C.), but KANT'S *Universal Natural History and Theory of the Heavens* (1755 A. D.) appears to offer for the first time an hypothesis of the general form and structure of our stellar system substantially in accord with present ideas.

> "Mr. WRIGHT of Durham, whose treatise I have come to know from the Hamburg publication entitled the *Freie Urteile*, of 1751, first suggested ideas that led me to regard the fixed stars not as a mere swarm scattered without visible order, but as a system which has the greatest resemblance with that of the planets; so that just as the planets in their system are found very nearly in a common plane, the fixed stars are also related in their positions, as nearly as possible, to a certain plane which must be conceived as drawn through the whole heavens, and by their being very closely massed in it they present that streak of light which is called the Milky Way. I have become persuaded that because this zone, illuminated by innumerable suns, has very exactly the form of a great circle, our sun must be situated very near this great plane."—HASTIE'S translation, page 30.

> "Whoever turns his eye to the starry heavens on a clear night will perceive that streak or band of light which on account of the multitude of stars that are accumulated there more than elsewhere, and by their getting perceptibly lost in the great distance, presents a uniform light

which has been designated by the name Milky Way. It is astonishing that the observers of the heavens have not long since been moved by the character of this perceptibly distinctive zone in the heavens, to deduce from it special determinations regarding the position and distribution of the fixed stars. For it is seen to occupy the direction of a great circle, and to pass in uninterrupted connection round the whole heavens: two conditions which imply such a precise destination and present marks so perceptibly different from the indefiniteness of chance, that attentive astronomers ought to have been thereby led, as a matter of course, to seek carefully for the explanation of such a phenomenon.

"As the stars are not placed on the apparent hollow sphere of the heavens, and as some are more distant than others from our point of view and are lost in the depths of the heavens, it follows from this, that at the distances at which they are situated away from us, one behind the other, they are not indifferently scattered on all sides, but must have a predominant relation to a certain plane which passes through our point of view and to which they are arranged so as to be found as near it as possible. This relation is such an undoubted phenomenon that even the other stars which are not included in the whitish streak are yet seen to be more accumulated and closer the nearer their places are to the circle of the Milky Way.

"If we now imagine a plane drawn through the starry heavens and produced indefinitely, and suppose that all the fixed stars and systems have a general relation in their places to this plane so as to be found nearer to it than to other regions, then the eye which is situated in this plane, when it looks out to the field of the stars, will perceive on the spherical concavity of the firmament the densest accumulation of stars in the direction of such a plane under the form of a zone illuminated by varied light. This streak of light will advance as a luminous band in the direction of a great circle, because the position of the spectator is in the plane itself. This zone will swarm with stars which, on account of the indistinguishable minuteness of their clear points that cannot be severally discerned and their apparent denseness, will present a uniformly whitish glimmer,—in a word, a Milky Way. The rest of the heavenly host whose relation to the plane described gradually diminishes, or which are situated nearer the position of the spectator, are more scattered, although they are seen to be massed relatively to this same plane. Finally, it follows from all this that our solar world, seeing that this system of the fixed stars is seen from it in the direction of a great circle, is situated in the same great plane and constitutes a system along with the other stars."—HASTIE's translation, pages 54-56.

"I come now to that part of my theory which gives it its greatest charm, by the sublime idea which it presents of the plan of the creation. The train of thought which has led me to it is short and natural; it consists of the following ideas. If a system of fixed stars which are related in their positions to a common plane, as we have delineated the Milky Way to be, be so far removed from us that the individual stars of which it consists are no longer sensibly distinguishable even by the telescope; if its distance has the same ratio to the distance of the stars of the Milky Way as that of the latter has to the distance of the Sun; in short, if such a world of fixed stars is beheld at such an immense distance from the eye of the spectator situated outside of it, then this world will appear under a small angle as a patch of space whose figure will be circular if its plane is presented directly to the eye, and elliptical if it is seen from the side or obliquely. The feebleness of its light, its figure, and the apparent size of its diameter will clearly distinguish such a phenomenon when it is presented from all the stars that are seen single."—HASTIE's translation, pages 61-62.

(b) I was immensely interested to find that Sir WILLIAM HERSCHEL had applied spectrum analysis, in a very elementary way, to six first-magnitude stars as early as the year 1798. The Harvard classification is appended for comparison:—

"By some experiments, on the light of a few of the stars of the first magnitude, made in 1798, by a prism applied to the eye-glasses of my reflectors, adjustable to any angle and to any direction, I had the following analyses:—

"The light of *Sirius* consists of red, orange, yellow, green, blue, purple, and violet. (Harvard Class A.)

"α *Orionis* contains the same colours, but the red is more intense, and the orange and yellow are less copious in proportion than they are in *Sirius*. (Class Ma.)

"*Procyon* contains all the colours, but proportionally more blue and purple than *Sirius*. (Class F5.)

"*Arcturus* contains more red and orange and less yellow in proportion than *Sirius*. (Class K.)

"*Aldebaran* contains much orange, and very little yellow. (Class K5.)

"α *Lyræ* contains much yellow, green, blue, and purple." (Class A.) —*Philosophical Transactions*, 1814, page 264.

I now find that a few authors have commented upon these observations by HERSCHEL: NEWCOMB and HOLDEN's *Astronomy*, 4th Ed., page 468; Professor HOLDEN in *Sir William Herschel, His Life and Works*, page 196; and Miss CLERKE in *The Herschels and Modern Astronomy*, page 163.

HERSCHEL's results for these six stars are in general correct, as tested by modern standards, tho the estimated distribution of the light of different colors differs in some details.

It should be noted that these observations, made in 1798, were not published until 1814, which was approximately the time when FRAUNHOFER's observations were beginning.

COMPARISON OF THE CONTINUOUS SPECTRA OF SOME LARGE AND SMALL PROPER-MOTION STARS.

By W. S. Adams.

In a recent number of the *Astrophysical Journal* I gave the results of a comparison of the relative intensity at about λ 4200 and λ 5000 of the spectra of a few pairs of stars of large and small proper motion which had identical spectral types. The spectra of the two stars were obtained upon the same plate and at as nearly as possible the same zenith distance. A considerable majority of the photographs showed the spectrum of the star of small proper motion to be distinctly weaker at the violet end of the spectrum than that of the star of large proper motion. A few pairs showed little or no difference, but in no case was the spectrum of the small proper-motion star stronger in the violet.

The amount of material available for this comparison was small. Accordingly, it seemed desirable to make an attempt to see whether the large number of radial velocity photographs could not be utilized for a similar purpose. For individual stars, of course, the results would be of little value, since the plates were taken at different zenith distances, under varying atmospheric conditions, and subjected to different development. For the mean of a considerable number of photographs and stars, however, these effects should counteract each other largely, and it seemed probable that results of some interest could be obtained.

The spectra compared were those of about one hundred stars of large proper motion, whose parallaxes have been measured, and of about sixty stars of very small proper motion with spectral types ranging between F and M. No plates were included which were obtained at very great zenith distances, or under unfavorable conditions of transparency. The method of comparison employed, tho necessarily very crude as compared with photometric measures of density, had the advantage of rapidity, and appeared to be sufficiently accurate for the character of the material available. A standard plate of α *Tauri* was first obtained, several spectra taken with different exposure times being placed side by side on the negative. The photograph of each star was then compared with the standard plate under a spectrocomparator, and estimates were made of the intensity of its continuous spectrum relative to that of α *Tauri* at three selected points at the violet end of the spectrum, and four points at the red end. The estimates were made in tenths of a unit between two of the α *Tauri* exposures. Thus 1.4 means that the density of the continuous spectrum is estimated to be 0.4 greater than the first spectrum of α *Tauri*, or 0.6 less than the second spectrum. After the comparisons had been finished the α *Tauri* photograph was measured under a Hartmann micro-photometer and the densities calculated. The results for all of the stars were then reduced to densities. Since the plates of both large and small proper-motion stars were taken at random during the estimation of intensities, and since the comparison is purely differential, it is difficult to see how any considerable systematic error could have entered into the results.

The values for the groups of stars compared are given below, the density scale being an arbitrary one which depends on the photographic wedge in the micro-photometer:—

	Number of Stars	Average μ	Average Type	Density at λ 4220	Density at λ 4599
F0 - F9	10	0″.012	F4	0.25	0.37
	23	0 .66	F6	0.32	0.37
G0 - G4	8	0 .009	G3	0.22	0.41
	30	0 .64	G2	0.33	0.41
G5 - G9	14	0 .011	G7	0.25	0.48
	22	0 .64	G7	0.40	0.48
K0 - K4	24	0 .011	K2	0.16	0.44
	20	0 .70	K1	0.31	0.44
K5 - K9	5	0 .012	K5	0.15	0.51
	5	2 .18	K7	0.27	0.51

The result for the K5-K9 groups is of low weight, the number of stars being small, and the spectra too faint at the violet end. The star 61^{2} *Cygni* is included in this group, which accounts for the very large proper motion.

The two features of note in these results are:—

1. The small proper-motion stars are decidedly weaker at the violet end of the spectrum than the large proper-motion stars.

2. The difference is least for the F stars, and increases with advancing spectral type at least as far as K.

The latter result is in agreement with a few observations on A type stars which show essentially no difference at the violet end of the spectrum between two groups of stars having proper motions of 0″.020 and 0″.13. It is true, however, that if the proper motions are interpreted in terms of distance the difference of distance indicated is much less between the two groups of A stars than between the groups of F to K stars given above. Hence on the basis of absorption of light in space it might not be possible to detect a difference in the violet portion of the spectrum for such a comparatively small difference of distance. The different groups of F, G and K stars, however, have so nearly the same average proper motion that should further observations confirm the change in the amount of absorption in the violet, it would seem almost inevitable to ascribe at least a part of the effect to conditions in the stellar atmosphere. In other words, to an effect of absolute magnitude, as Professor KAPTEYN concisely describes it.

ASTRONOMICAL OBSERVATIONS IN 1913.

Made by Torvald Köhl, at Odder, Denmark.

Variable Stars.

(The instrument used is a 3-inch Steinheil, power 42.)

S *Ursæ Majoris.*[1]

Jan. 2: S = d.
5: 2 steps > d.
9: = d.
26: 2 steps > d.
30: 1 step > d.
Feb. 8: 2 steps > d.
22: 1 step < e.
25: id.
Mar. 5: 2 steps < e.
8: 3 steps < e.
12: 3 steps > f′.
22: half way between e and f.
24: 1 step > f′.
26: id.
Apr. 2: 1 step < f.
4: half way between f and g.
8: id.
May 8: invisible
July 29: half way between c and d.
Aug. 1: 3 steps > d.
24: 4 steps > d.
27: 2 steps > d.
29: id.
30: id.
31: 1 step > d.
Sept. 6: ½ step > d.
7: 1 step > d.
12: = d.
22: id.
27: ½ step < d.
29: = e.
Oct. 21: 3 steps > f.
27: id.
Nov. 4: = f′.
19: half way between f and g.
30: 1 step < g.
Dec. 24: 3 steps < g.

T *Ursæ Majoris.*[2]

Jan. 2: T = b.
5: id.
9: 1 step > c.
26: 1½ step < d.
30: 1½ step > e.
Feb. 8: 1 step > e.
25: 2 steps < g.
Mar. 8: faint.
12: very faint.
22: invisible.
24: id.
Mar. 26: id.
Apr. 2: id.
4: id.
8: id.
May 8: id.
July 29: = a in the sketch on S.
Aug. 1: id.
24: = b in the sketch on S.
27: id.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 73, 12, 56.
[2] Vide the sketch in the *Publications A. S. P.*, No. 22, 4, 63.

Aug. 29: = c in the sketch on S.
30: id.
31: id.
Sept. 6: 3 steps > a.
7: id.
12: 1 step > a.
22: = a.
27: < b. > c.

Sept. 29: = b.
30: id.
Oct. 21: 2 steps > e.
27: = e.
Nov. 4: half way between e and g.
19: 3 steps < f.
Dec. 24: invisible.

W *Pegasi.*[1]

Jan. 3: W 2 steps < h.
26: invisible.
July 29: 1 step < b.
Aug. 1: = b.
24: half way between b and c.
27: id.
29: id.
31: 2 steps > c.
Sept. 7: 2 steps > c.
12: 1 step > c.

Sept. 22: = c.
27: 2 steps < c.
29: id.
Oct. 21: = e.
27: 2 steps < e.
Nov. 4: = f.
19: = g.
22: = h.
30: ½ step > h.
Dec. 24: < h. > n.

SS *Cygni.*[1]

Jan. 2, 8^h: SS invisible.
9, 6^h: very faint.
26, 6^h: invisible.
Feb. 9, 8^h: = id.
May 8, 10^h: invisible.
July 29, 11^h: very faint.
Aug. 1, 10^h: id.
24, 10^h: = ^{h}.
27, 9^h: id.
29, 9^h: id.
31, 9^h: id.
Sept. 4, 9^h: = g.
5, 9^h: half way between c and d
6, 9^h: = c.
7, 9^h: 1 step > c.
12, 9^h: 1 step < c.
13, 8^h: 2 steps < c.

Sept. 19, 8^h: 2 steps < d.
22, 8^h: < f. > g.
23, 8^h: = f.
29, 8^h: < g. > h.
Oct. 21, 8^h: id.
27, 11^h: invisible.
31, 9^h: < g. > h.
Nov. 6, 8^h: 2 steps < d.
19, 6^h: half way between d and e
24, 6^h: = h.
30, 7^h: 2 steps < g.
Dec. 17, 6^h: = h.
24, 8^h: 2 steps < h.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 141, **24**, 109.

Z *Cygni.*[1]

Jan. 2: Z 1 step < c.
5: = c.
9: id.
26: 1 step > b.
Feb. 9: = b.
May 8: 3 steps < e.
Aug. 1: invisible.
Aug. 25: = e.
Aug. 27: id.
Sept. 4: = d.
7: 2 steps > d.
Oct. 27: 2 steps > b.
Nov. 19 { half way between a and b.
Dec. 7: = b.

U *Herculis.*[2]

May 8: V = e.
July 29: 2 steps < h.
Aug. 1: id.
24: id.
27: 4 steps < h.
Aug. 31: id.
Sept. 7: 5 steps < h.
22: 6 steps < h.
Oct. 21: utmost faint.

S *Persei.*[3]

Feb. 9: S = a.
22: 1 step > a.
Mar. 12: = a.
26: id.
Apr. 2: id.
8: 2 steps > a.
22: = a.
Aug. 1: = d.
24: 2 steps < c.
27: = d.
Sept. 22: = d.
Oct. 21: id.
Nov. 4: ½ step > e.
30: 2 steps > f.

Var. 25, 1913, *Ursæ Majoris.*

(This star = B. D. + 60° 1412 ($9^m.5$) = *f* in the sketch on T *Ursæ Majoris.*

Jan. 2: f 1 step > g.
5: 2 steps > g.
9: = g.
Feb. 8: 2 steps > g.
9: id.
25: = g.
Mar. 12: 1 step > g.
24: 2 steps > g.
26: id.
Apr. 2: id.
4: = g.
8: 1 step > g.
Aug. 1: 2 steps < g.
Aug. 24: = g.
29: 2 steps < g.
30: id.
31: id.
Sept. 6: ½ step < g.
7: id.
22: 1 step < g.
29: 2 steps > g.
30: 1 step < g.
Oct. 21: = g.
Nov. 4: 1 step > g.
19: id.
Dec. 24: = g.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 100, **17**, 16.
[2] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 42.
[3] Vide the sketch in the *Publications A. S. P.*, No. 135, **23**, 43.

Several other stars have been watched, such as Y *Tauri* (B. D. + 20° 1083), which on January 5th, 31st, and February 8th was a little fainter, but on February 25th, March 22d, 24th, April 2d, 6th, 8th and 14th a little brighter than the star B. D. + 20° 1095. — TV *Cygni*[1] has in the past year only shown small variations, being either equal to or a little brighter than C.

LARGE METEORS.

Fireballs have been observed from stations in Denmark and surrounding countries on the following dates: January 27th (sixteen observations from Denmark, one from the North Sea, and one from Scotland), March 24th, April 1st, 8th, 28th, May 28th, June 6th, July 26th, 28th, 30th, August 9th, 18th, September 6th, 23d, 24th, October 2d, 21st, 31st, November 4th, 10th, 18th (two meteors), 19th, 23d (three meteors), 26th, 27th, 28th, December 2d, 18th, 24th. One of the two under November 18th named meteors was especially interesting. A great fireball with a long tail was seen and the *meteorite fell down* in the sea near Dyrvik on Fröya at Trondhjem, Norway, after having hit and demolished the mast of a yacht in the harbor and a pane was cracking into an adjoining house at the same time.

SHOOTING-STARS.

Shooting-stars were observed from seven stations in Denmark from August 9th to 12th. At these stations 116 paths of shooting-stars were mapped and four proved suitable for calculation, under which two fireballs were included — the meteors on April 8th and October 21st. These four meteors have given the following results:—

From Observation.

No.	Time, P. M.	Station.	Beginning.	Ending.	Mag.	Observer.
1	Apr. 8, 9^h 5^m	Odense	290° + 69°	342° + 63°	♀	C. T. Busk.
		Copenhagen	49 + 53	39 + 42.5	♀	A. Fock.
2	Aug. 9, 10 42.5	Odder	336 + 64	317 + 59	2	T. Köhl.
		Jyderup	222 + 71.5	213 + 54	2	M. Povlsen.
3	Aug. 12, 10 14	Nyborg	....	12 + 26	♃	T. Vaabek.
		Möen	....	172 + 49	♃	Kierulff.
4	Oct. 21, 10 43	Odense	....	80 + 30	1	C. T. Busk.
		Copenhagen	....	324 + 24	1	Kierulff.

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[1] Vide the sketch in the *Publications A. S. P.*, No. 135, 23, 43.

From Calculation.

No.	Beginning.			Ending.			Real length of the path.	Radiant.	
	h	λ	φ	h	λ	φ	β	AR	Decl.
1	99.9	1° 36′.3 W	56° 28′.9	91.2	2° 30′.1 W	56° 52′.1	71.2	202°	÷ 14°
2	117.2	1 49.9 W	56 14.2	77.7	2 10.1 W	56 2.5	50	194	+ 65
3				32.9	0 44.9 W	55 24.6			
4				56.4	0 51.3 W	55 27.5			

h and β are expressed in kilometers; λ is longitude from Copenhagen; φ is north latitude; h is the altitude of the meteor above the Earth's surface.

The Carina-Meteor catalog has now reached a number of 5.609 meteors, observed from stations in Denmark and surrounding countries from 1875 to 1913, inclusive.

From August 11th to 16th, inclusive, astronomical lectures were held at the Carina Observatory in Odder.

In the estimation of variable stars I often have been assisted by Mr. J. SKAKKE, who also, by the aid of a Darlot-lens, has undertaken a work on stellar photography.

PLANETARY PHENOMENA FOR MAY AND JUNE, 1914.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

First Quarter..	May 2,	10^h 29^m P.M.	First Quarter..	June 1,	6^h 3^m A.M.
Full Moon	" 9,	1 31 P.M.	Full Moon ...	" 7,	9 18 P.M.
Last Quarter..	" 16,	2 12 P.M.	Last Quarter..	" 15,	6 20 A.M.
New Moon ...	" 24,	6 35 P.M.	New Moon ...	" 23,	7 33 A.M.
			First Quarter.	" 30,	11 24 A.M.

The Sun reaches the summer solstice and summer begins on June 21st shortly before 11 P. M., Pacific time.

Mercury on May 1st is a morning star, rising about three-quarters of an hour before sunrise, and is therefore too near the Sun for naked-eye observations. It moves on toward superior conjunction, reaching it and becoming an evening star on the morning of May 17th. The apparent distance between the bodies rapidly increases, and by June 1st the planet remains above the horizon nearly an hour and a half after sunset. On June 18th the planet reaches its greatest east elongation, and will then remain above the horizon a little more than an hour and three quarters after sunset. After this the planet and the Sun approach each other, but the distance between them remains great enuf so that the planet remains above the horizon more than an hour after sunset, until after the end of the month. Therefore from the last week in May until July *Mercury* is in good position for evening observation, and about the middle of June it is in a specially good position. This is by far the best period of the year for seeing this planet. The greatest east elongation, 24° 52′, is larger than the average, as the planet comes to its aphelion on July 3d. Also at the end of May *Mercury's* heliocentric latitude is greatest; that is, it is about 2° north of the Sun's path, and this retards its setting some minutes. On May 28th it is in conjunction with *Saturn*, but the nearest approach is 3°, and it occurs during daylight in the United States. On June 25th, 2 P. M. Pacific time, it is in conjunction with *Neptune*, the latter being only 10′ north.

There will be another conjunction of the same planets on July 8th.

Venus remains an evening star, being a little farther from the Sun and in better position for observation than during the early spring. On May 1st the planet remains above the horizon somewhat more than an hour and one half after sunset. This interval increases to rather more than two hours by June 1st and remains practically constant thruout that month. The planet on May 1st is in the constellation *Taurus* between the *Pleiades* and *Hyades*, and moves eastward out of *Taurus* thru *Gemini* and *Cancer* almost to *Leo*. On the morning of May 16th it is in conjunction with *Saturn*, but the nearest approach is not close and occurs during daylight in this country. It is also in conjunction with *Neptune* on June 16th, 6 P. M. Pacific time, passing 2° 14′ north of the latter.

Mars is still in good position, but its apparent distance from the Sun is gradually growing smaller. On May 1st it remains above the horizon until nearly 1 A. M., but by the end of June it sets at about half-after 10 P. M. During the two months it moves 33° eastward and 11° southward from the constellation *Cancer* into *Leo*. On June 23d it passes less than 1° south of the first-magnitude star *Regulus*, *a Leonis*. It will then be distinctly less bright than the star, its brightness being only about 10 per cent of that which it had at the time of opposition early in January. Its minimum brightness, about that of a standard second-magnitude star, like the pole star, will, however, not be reached for several months. Its actual distance from the Earth is still growing rapidly larger, changing from 141,000,000 to 187,000,000 miles during the two months. On May 30th and again on June 27th the Moon passes very close to it, the planet being occulted for certain parts of the Earth on the first of the two dates.

Jupiter rises on May 1st shortly before 2 A. M. and on June 30th at about 10 P. M. It is in the eastern part of the constellation *Capricorn* and up to June 11th it moves slowly about 2½° eastward. It then begins to move westward along a line a little to the south of its line of eastward motion and at the end of June will be nearly in the position it held on May 23d. On the evening of June 12th it will be in very close conjunction with the Moon and will be occulted for certain portions of the southern hemisphere.

Saturn remains an evening star until the morning of June 13th, when it passes conjunction with the Sun and becomes a morning star. During most of the two months' period, therefore, it is too close to the Sun for naked-eye observation. On May 1st it sets not quite three hours after sunset, but before the end of the month the interval shortens to considerably less than one hour, and the planet will then not be bright enuf to be seen in the evening twilight. By the end of June it will rise not quite an hour before the Sun. The planet is in the eastern part of the constellation *Taurus* and moves about 8° eastward during the two months. Its conjunctions with *Mercury* and *Venus* have already been mentioned.

Uranus rises on May 1st at about half-after 1 A. M. and at about 9:30 P. M. on June 30th. It is nearly stationary in the constellation *Capricorn,* moving a little eastward until May 17th and then moving westward, but the whole motion is less than 1°. There is no bright star near it, but during the early part of May it is about 1° west and a little south of the fourth-magnitude star *θ Capricorni*. After the middle of May it moves away from the star toward the west.

Neptune is in the western sky in the evening, not setting until after midnight on May 1st, and somewhat after eight on June 30th. It remains near the dividing-line of *Gemini* and *Cancer.*

LIBRARY NOTICE—WANTED.

In order to complete our files for binding, the following missing numbers are wanted to *Monthly Notices* of the Royal Astronomical Society:—

Nos. 1, 2 and 4 of Vol. LXVI.
No. 5 of Vol. LXIX.
No. 1 of Vol. LXX.

If any of our members or readers are in possession of these numbers and find it in their hearts to contribute them to the Society, their kindness will be gratefully appreciated.

Send to the Librarian of the Astronomical Society of the Pacific, 752 Phelan Building, San Francisco, Cal.

NOTES FROM PACIFIC COAST OBSERVATORIES

[illegible] Spectrum of Nova Geminorum No. 2

[illegible] February we received from Professor Barnard a [illegible] that according to observations with the 40-inch [illegible] of Nova Geminorum No. 2 which in [illegible] had differed by [illegible] from that of an ordinary [illegible] normal position. [illegible] observations [illegible] years [illegible] by Professor [illegible] in the character of the spectrum [illegible] in this way.

[illegible] we [illegible] of the spectrum of Nova Geminorum [illegible] the [illegible] reflector with a [illegible]. A comparison of this negative with one taken [illegible] very interesting differences [illegible] for the variation of focus observed by [illegible]. The [illegible] light [illegible] the light being concentrated in [illegible] the relative [illegible] were by far the brightest. The February [illegible] a strong [illegible] in the relative intensity of these [illegible] with [illegible].

[illegible] observations [illegible] Professor Barnard [illegible]. The focal length of the [illegible] that of [illegible] visually corrected [illegible] wave-length about λ 5600 [illegible] the [illegible]. According [illegible] the focus of an [illegible] the [illegible] strong [illegible] by the [illegible] of the [illegible] wave-length. In the case of Nova Geminorum [illegible]

November the absence of continuous spectrum left very little of the light of the star in the λ 5600 region. The "effective wave-length" therefore of the integrated light being determined to a considerable extent by the strong bands at λ 4365 and λ 5007, was decidedly shorter than for an ordinary star. Hence the focal length as determined by the eye was longer. In February the presence of the continuous spectrum and, to a less extent, the weakening of the two bands referred to, brought the effective wave-length back to that of an ordinary star. The change should be accompanied by a certain amount of change in color, and Professor BARNARD states that the star, which appeared bluish-white in October, was white in February.

A marked feature of the February photograph of the spectrum is the very great intensity of the principal series line of hydrogen at λ 4686. It is fully equal to the chief nebular line at λ 5007. W. S. ADAMS and F. G. PEASE.

NOTES ON THE ONE-HUNDRED-INCH TELESCOPE.

During the winter no very large amount of optical work has been performed on the 100-inch disk, altho the spherical figure has been nearly perfected. It has been found impossible to guard completely against the wide variations of temperature due to weather changes in the winter months, and accordingly it has seemed preferable to delay some of the work requiring the greatest accuracy until conditions are more favorable. In the meantime the 60-inch plane mirror to be used in testing the parabolization of the large disk has been completed. In addition, certain changes have been made on the grinding machine to facilitate the use of a small tool in parabolizing.

The mounting has made considerable progress at the Fore River Shipbuilding Works at Quincy, Massachusetts. Among the portions already cast and machined are the north and south pedestals (the former in four sections), the mercury tanks and floats, and portions of the polar axis. Meanwhile the driving clock has been under construction in Pasadena and is nearly ready for assembling. According to present plans the entire mounting, with the exception of a portion of the tube and the driving mechanism, will be erected at Quincy previous to shipment.

The first carload of structural steel for the stationary part of the telescope building is expected within a few days. We hope to be able to erect on Mount Wilson during the coming summer this portion of the building, which will include the side walls and the rails upon which the dome will rotate. To facilitate the transportation of this material, as well as of the very large and heavy sections of the telescope mounting at a later date, considerable work has been done on the mountain road during the winter. Although this work has been much handicapped by remarkably heavy rainstorms, about five miles of the road has been widened by an average amount of four feet, the minimum width of the road-bed for this portion now being twelve feet. At the sharper turns deep excavations have been made to obviate the necessity for "backing" the motor trucks used in transportation. We expect to complete the widening of the remaining four miles of the road next winter.

W. S. ADAMS.

D. O. MILLS EXPEDITION.

Mr. ARTHUR A. SCOTT, Instructor in Mathematics in the Instituto Ingles, Santiago, Chile, has been appointed Assistant in the D. O. Mills Observatory on Cerro San Cristobal, Santiago.

W. W. CAMPBELL.

THE SPECTRUM OF η CARINÆ.

Located on the edge of the perforation in the great "Keyhole Nebula" are a number of faint stars, among which is the well-known variable η *Carinæ*, or η *Argus*, at present invisible to the unaided eye and only distinguished from its neighbors by its slightly greater brightness and deep red color. It has, however, not always been such an inconspicuous object. Of the fourth magnitude in 1677, when first observed by HALLEY at St. Helena, it appears to have risen to the second some eight years later. At the beginning of the last century it was again a star of the fourth magnitude. Then followed a period of violent changes in light. A maximum was attained in 1843, at which time it was only slightly inferior in brightness to *Sirius*. Slowly it declined to the first magnitude in 1856 and then rapidly descended until it became invisible to the naked eye in 1868.

A stationary minimum of about seven and a half was reached in 1885, and there it has since remained, with occasional fluctuations up or down of a few tenths of a magnitude. All attempts to deduce a period for the variation in light of η *Carinæ* have failed, and it seems probable that this star belongs to the class of variables known as temporary stars or novæ.

The spectrum of this interesting star has been studied photographically with objective prism spectrographs at the Arequipa Station of Harvard College Observatory and at the Cape Observatory. A spectrogram with a one-prism slit-spectrograph was also secured by GILL at the Cape Observatory in 1899. In further study of its spectrum three spectrograms were obtained by the authors on March 29, 1912, and March 11 and 28, 1913, with the one-prism slit-spectrograph of the D. O. Mills Expedition, Santiago, Chile. The values of the wave-lengths of the lines determined from measures of these plates and a discussion of the results are given in *Lick Observatory Bulletin*, No. 252. From our study of the spectrum of η *Carinæ* as exhibited on our spectrograms we have drawn the following conclusions:—

1. The spectrum of η *Carinæ* on our spectrograms is essentially a bright-line spectrum.

2. A number of the bright lines have been identified with enhanced lines of iron, titanium, and chromium.

3. The enhanced iron lines are displaced toward the violet from their normal position by 0.42 A. On the assumption that this displacement is a Doppler effect, it corresponds to a velocity of approach of 28^{km} per second.

4. There is some evidence that the titanium and chromium lines show a mean displacement to the violet 0.2 A greater than that of the iron lines.

5. The iron lines are in general the stronger lines, while the lines of titanium and chromium appear only among the weaker ones.

6. Several strong lines in η *Carinæ* have not been identified with known lines.

7. Some evidence is presented that the hydrogen lines are double.

8. The lines of helium, the nebular lines, and magnesium 4481 A are not present on any of our spectrograms.

9. A comparison of the spectrum of η *Carinæ* with that of novæ in the early period of their history indicates a close connection between the two spectra. This fact and the great fluctuation in light exhibited by this star in the past lend support to the view frequently expressed, that η *Carinæ* is a nova. Further support arises from the apparent location of this star in a great nebula.

J. H. MOORE and R. F. SANFORD.

A REMARKABLE THUNDER STORM.

The thunder storm which occurred shortly after midnight of February 18th-19th gave an exhibition of fireworks and noise which the Lick Observatory community will never forget. The conditions were very dramatic. When I was first awakened, the interval between the flash and the thunder was ten seconds; then it was successively nine, eight, seven, six, five and four seconds. This meant that the storm was approaching us and that the electrical discharges were less than a mile away. Next the interval was three seconds, and I felt sure that we were in for trouble. The two following discharges were two seconds or less away, and it is probable that these were the ones which connected with the steel dome of the 36-inch refractor. A few seconds later there were two discharges which must have hit the hill on which my residence stands (Ptolemy), for the swish of the discharges through the air was heard a minute fraction of a second before the blinding flash and the deafening crash occurred, the flash and the crash being simultaneous. Having paid its compliments, the storm continued on its way, with increasing time intervals between flash and report.

The lightning struck many times within the region occupied by the observatory buildings and residences. The great dome was struck once certainly, and twice probably. A small fire was started at a harmless point in the basement of the great dome. It was found promptly and put out without effort or excitement. The electric-lighting and power plant and the telephone system were early put out of commission. Fuses were melted in all of the buildings, and many electric lamps were exploded. Coils in several of the electric motors were burned out; copper wires were melted here and there; and all of the meters which measure the flow of current in the various buildings were damaged. Fortunately, there was no personal injury.

California is remarkably free from thunder storms, except in the high Sierras, and it was quite out of harmony with our traditions that Mount Hamilton should have serious trouble from this source. We are considering ways and means of future protection against lightning.

Lightning discharges on Mount Hamilton seem to be closely associated with sleet storms. The disturbance of February 18th-19th was accompanied by a downfall of diminutive hail stones. The ground was covered with ice balls a quarter of an inch or less in diameter. I recall that on two or three former occasions a fall of sleet was accompanied in each case by a single sharp discharge of lightning, which occurred without warning and did not repeat itself. W. W. CAMPBELL.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these *Publications*, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

THE LINES OF MAGNESIUM.[1]

The spectrum of magnesium has recently been investigated by Professor FOWLER at the South Kensington Laboratory, London, with a view to find series among the lines analogous to those of hydrogen. His previous investigation of the hydrogen spectrum as given by a vacuum arc led to the production for the first time in the laboratory of the sharp series which before had been found only in *Zeta Puppis* and similar stars; also to the discovery of a second principal series and of four members of the first principal series, the first of which corresponds to the line 4686 found in nebulæ and Wolf-Rayet stars. It seemed then that hydrogen was unique in having two principal series converging to the same limit of frequency like the diffuse and sharp series. It is now found that the magnesium spectrum from the vacuum arc contains at least one pair of series converging to a limit of frequency. This pair of series is in the violet and ultra-violet, and another is suspected in the visual region to correspond with the diffuse and sharp series of hydrogen. Just as the first line of the first principal series of hydrogen 4686 is a conspicuous stellar line, so the first line of the first of the two new magnesium series is a conspicuous stellar line in classes A and B. Professor FOWLER measures the wave-length on his plates as 4481.35. It is a strong line in the spark spectrum of magnesium. It is as strong as helium in many early-type stars. FROST and ADAMS determined its wave-length from their stellar plates to be

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[1] By A. FOWLER, South Kensington, London, *Proceedings of the Royal Society*, [illegible], 133, August, 1913.

4481.40. A significant result of Professor Fowler's measurements is the practically constant difference of frequency of about a thousand units between each line of the new magnesium series and the corresponding line of the principal series of hydrogen.

The well-known Rydberg series of single lines given by the arc in air are very diffuse. Fowler has found them quite sharp in the vacuum arc and has obtained more accurate measures of their wave-lengths. Three of these lines in the blue region were known to correspond to solar lines. The succeeding four toward the violet are now seen to correspond with solar lines, so that it is very certain that the Rydberg series of single lines exists in the solar spectrum. Professor Fowler finds that three other lines seem to be associated with the Rydberg series somewhat as the sharp series of hydrogen is associated with the diffuse series, but the correspondence is not exact. The following table give the measures of the several series investigated:—

First Fowler.	Second Fowler.	First Rydberg.	Second Rydberg(?).	Rowland Solar.
4481.35[1]	3104.91	....	5711.56[2]	5711.31
2661.00	2449.68	5528.75[2]	....	5528.64[3]
2329.68	2253.94	....	4730.34	4730.21
2202.75	2166.35	4703.33[2]	....	4703.18[3]
....	....	....	4354.53[5]	5354.43
....	....	4352.18[2]	....	4352.08[3]
....	....	4167.55	....	4167.44
....	....	4057.78	....	4057.67
....	....	3986.94	....	3986.90
....	....	3938.58[4]	....	3938.55
....	....	3904.17[4]	....	....
....	....	3878.73[4]	....	....
....	....	3859.39[4]	....	....

[1] Strongest line in magnesium spark and strong in early type stars.
[2] Measures by Kayser and Runge.
[3] Previously identified with magnesium.
[4] Discovered in the vacuum by Fowler in the present investigation.
[5] Predicted by Fowler from his formula and at once found on his plates.

The discovery in the laboratory of stellar lines and the determination of their wave-lengths is of great help in determining the radial velocities of stars and in dealing with the questions of the physical condition of stellar masses and their atmospheres as regards their temperature, pressure, density, intrinsic luminosity, energy, radiation, character of spectrum, whether emission, absorption, or both of these with the phenomena of reversal. The conditions under which lines appear in the laboratory may give an indication of the stellar condition of the star in which they are found with similar characteristics. FOWLER's investigations, therefore, lend great aid to astrophysics. G. F. PADDOCK.

FLEXURE OF MIRRORS: EFFECT UPON RESOLVING POWER.[1]

This investigation is an attempt to deal with the effect of the bending of a mirror upon the image which it may form. A brief statement of the problem and attending conditions is as follows: Resolving power is proportional to aperture. Distortion of the figure due to weight of mirror and form of support will impair the resolving power. Increasing apertures for mirrors of same thickness and same form of support may gain no resolving power. There may be a critical aperture beyond which resolving power may decrease. The object of the paper is to calculate the distortion for various forms of support and the effect on resolving power and the limits of aperture permissible. The difficulties of analysis permit the consideration of only simple forms of support, but they are sufficient to show whether the critical aperture is beyond the limit of practicable construction.

The analysis is based upon the equations of elastic equilibrium in the theory of elasticity. The horizontal and vertical positions of the mirror are treated, the inclined position being considered a combination of the other two. The back supports considered are those at the center, at the rim, and on a circle between center and rim. The formulæ first deduced give the relative depression of center and rim or of any point of the radius with respect to the fixed center or rim. Further formulæ deal with the breadth of the image of a point source of light and the effect upon it of the flexure of the mirror; whence follow expressions for the limit of aperture beyond which the breadth of the image decreases the resolving power. Assuming the thickness to be one tenth the aperture, the limit of aperture is eight inches for support at the circumference; for supports at both center and rim, the limit is about four feet; for supports at center, at rim, and midway between, the limit of aperture is about ten feet. By increasing the thickness of the mirror, the limit of aperture is increased, but the thickness may be determined by the process of casting the glass, the homogeneity of the glass, and the amount of weight feasible to support. It is obvious that more complete back supports than those mentioned increase the limit of aperture beyond practicable sizes of mirrors. Further discussion of the distortion in the plane of the morror, due to inclined or vertical positions, shows that it is impossible to prevent displacements tangential to the rim, but the normal displacements can be prevented by rim supports. On the vertical position, assuming the focal length to be five times the aperture, the limit of aperture is about twelve feet. By increasing the focal length the limit of aperture is increased.

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[1] By H. S. JONES, Cambridge, *Proceedings of the Royal Society*, 88, 494, July, 1913.

The conclusion reached is that with simple forms of support the critical aperture is greater than is practicable for construction. An example of the best system of support is that of the Mount Wilson 60-inch mirror, which has well-distributed back supports and a rim band with lateral supports.

G. F. PADDOCK.

ON A SIMPLE METHOD OF DETECTING DISCONTINUITIES IN A SERIES OF RECORDED OBSERVATIONS WITH AN APPLICATION TO SUN-SPOTS.[1]

Professor TURNER has been engaged for some time in analyzing WOLFE'S sun-spot numbers in a Fourier sequence, "arriving finally at the conclusion that none of the periodicities disclosed were continuous throughout the series." In the present paper, he resumes the discussion, beginning by describing a simple expedient for detecting the breaks in such a series. The method followed is exhibited in a detailed application to WOLFE'S numbers from 1749 on, which reveals discontinuities or breaks in the series, not introduced by the calculation and hence existing in the observational data. "These breaks are near the dates 1766, 1796, 1838, 1868, 1895, which are sufficiently close to those of *Leonid* perihelia to suggest a *vera causa.*"

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[1] By H. H. TURNER, *Monthly Notices R. A. S.*, **74**, **82**, **1913**.

Before discussing this hypothesis the author exhibits a table to show varying periods which best fit the sun-spot numbers. These are as follows: 1749-1767, 10.9 years; 1760-1796, 9.379; 1787-1838, 12.49; 1829-1870, 11.69; 1860-1894, 12.07; 1890-1911, 13.39.

The remaining portion of the paper is devoted to an exposition of his hypothesis that the *Leonid* meteor swarm is responsible for these discontinuities, or changes of period in sun-spot activity.

The *Leonids* cannot act directly, since the perihelion distance of the stream is about an astronomical unit; hence a secondary swarm is postulated. This swarm is assumed to revolve in about eleven years, with a very small perihelion distance, comparable to the Sun's radius. The major axis of the orbit is nearly five astronomical units, and the eccentricity is exceedingly high, $e = 1 - .001$. Hence, on any ordinary sized diagram, the orbit would be practically a straight line, resting one end on the Sun, with the other extending 10 A. U., approximately *Saturn's* distance, from the Sun. In such an orbit the velocity at the Sun end would be very great, at the other very small; hence the swarm would linger at aphelion, four fifths of the period being spent at a distance greater than 5 A. U. from the Sun, and half the period at a distance exceeding 8.5 A. U.

In this part of the orbit the swarm will be very sensitive to perturbations, and it is suggested that the *Leonid* swarm is the disturbing agent. This assumption is then investigated in detail, the perturbing effect of the *Leonids* on the swarm as it moves out toward aphelion and, later, when it returns, being taken into account.

Professor TURNER finds that by plausible assumptions of the relative positions of the hypothetical swarm and of the *Leonids*, the observed variation in periods can be explained.

The origin of this hypothetical swarm is then considered and the hypothesis is advanced that it is a portion of the *Leonid* swarm which has been detached by an encounter of the *Leonids* with *Saturn*. From a consideration of the periods of *Saturn* and of the *Leonids,* it is found that the year 301 A. D. "seems most promising" for this encounter, tho there are also arguments in favor of the year 271 A. D.

The author admits that "the foregoing theory depends on the fundamental assumption that the *Leonids* have sufficient mass to alter the period of the SSS [sun-spot swarm] very considerably. If so, they must also be able to perturb appreciably other bodies near which they pass, and particularly the Earth." The unexplained fluctuations in the Moon's motion are then examined and the conclusion is reached that they are quite consistent with disturbances at *Leonid* returns.

Professor TURNER further thinks it possible that the *Leonids* may be responsible for the unexplained secular movement of the perihelion of *Mercury.*

Finally, he finds no difficulty in accounting for the "equatorial acceleration" of sun-spots.

At the time of making this abstract no critical comment on Professor TURNER's hypothesis has been printed.

February, 1914. R. G. AITKEN.

PHOTOGRAPHIC METHODS IN LATITUDE WORK.

Most of the attempts which have been made in the past to employ photography in the investigation of the variation of latitude have failed to prove their superiority to visual observations. But a decided advance appears to have been made in this field by the recent work of Dr. F. E. Ross at Gaithersburg, Maryland, with a photographic zenith telescope of special construction.[1] "By a suitable mechanism the photographic plate is made to move in an east and west direction with the speed of a zenith star. Six images, of 14 seconds exposures each, are secured of each star, three before and three after reversal of the objective. The objective is 20^{cm} (7.87 inches) in diameter and has a focal length of 516^{cm} (20.31 inches). Stars of magnitude 8.5 can be photographed on an average night. The maximum zenith distance measurable is 10′." The accuracy of the results secured is very high; the greatest deviation from the mean of all Dr. Ross's observations in one month was 0″.20, and there was only one error of this magnitude. The probable error of one pair of stars is ± 0″.061, while the corresponding probable error of the same observer by the ordinary visual method, derived from observations extending over several years, is ± 0″.102.

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[1] *Astronomische Nachrichten,* 197, 137, 1914.

H. D. CURTIS.

A FAINT COMPANION TO CAPELLA.

An interesting discovery has been made by Dr. R. FURUHJELM of Helsingfors Observatory, from measures made on plates of the Helsingfors section of the *Carte Photographique du Ciel*. He finds that a faint star of photographic magnitude 10.6, slightly over twelve minutes of arc from *Capella*, is physically connected with the bright star. The faint star has almost precisely the same proper motion as *Capella*, both in direction and in amount. As *Capella* is itself a spectroscopic binary, the discovery of this distant companion adds additional interest to the system.

The special interest of the discovery lies in the relatively very great distance of the faint companion from the bright star. Adopting ELKIN's value for the parallax of *Capella*, its distance from our system is roughly forty-one light-years, and the faint companion star is at least one-seventh of a light-year, or over eight hundred billion miles from its bright primary.

H. D. CURTIS.

GENERAL NOTES

Napier Tercentenary Celebration. — JOHN NAPIER's *Logarithmorum Canonis Mirifici Descriptio* was published in 1614; and it is proposed to celebrate the tercentenary of this great event in the history of mathematics by a Congress, to be held in Edinburgh on July 24-27, 1914. The celebration will be held under the auspices of the Royal Society of Edinburgh. with the co-operation of numerous other societies. A general invitation has been issued by the committee in charge to all mathematicians and others interested. On two days of the meeting the historical and present practice of computation and other developments closely connected with NAPIER's discoveries and inventions will be discussed.

Dr. STROOBANT, of the Royal Observatory at Uccle, Belgium. with a number of his associates, proposes to issue soon a new edition of *Les Observatoires astronomiques et les astronomes*, which appeared in 1907. This valuable book of reference has become a sort of astronomical "Who's Who," and the new edition will be welcomed by astronomers and libraries. The committee in charge desires, as in the first edition, to include the names and addresses of professors of astronomy and amateurs who, though not attached to any observatory, are engaged in astronomical work.

Dr. H. F. BAKER, Fellow of St. John's College and Cayley lecturer in mathematics, has been elected Lowndean professor of astronomy and geometry in the University of Cambridge in succession to the late Sir ROBERT BALL.

The New Telescope for the Chabot Observatory.—The new telescope of twenty inches aperture for the Chabot Observatory is now in actual progress of building.

After the necessary legal advertising for bids, the offer of the WARNER & SWASEY COMPANY was accepted and the telescope ordered. The optical parts are to be furnished by BRASHEAR. The objective is to be of Jena glass, with a focal length of twenty-eight feet, two finders, of 4½ and 3 inches, micrometer, sidereal dial, quick-motion in right ascension, coarse and fine graduation of circles, driving clock wound by electric motor, full electric illumination of circles, etc.

The disks for the objective have already been ordered, and the WARNER & SWASEY COMPANY are at work on the mounting, which the company will exhibit at the Panama-Pacific Exposition. It is expected that the objective will be furnished before the Exposition closes, when the telescope will be taken to Oakland and installed in the new observatory, which will be built the coming autumn, on a site several miles from the business part of the city, where the present observatory is located.—From the March *Popular Astronomy*.

So far as present reports indicate, the eclipse track for the total solar eclipse of August 20th-21st next will be adequately covered at its different parts by a number of expeditions. Pulkova will establish three stations, one on an island in the Baltic, one at Kanev southeast of Kiev, and one at Feodosia in the Crimea. An expedition, under the auspices of the Joint Permanent Eclipse Committee of the Royal and the Royal Astronomical Societies, will be located at or near Kiev, the observers being Professor FOWLER, Mr. W. E. CURTIS, and Father CORTIE, with Major HILLS and Father O'CONNOR as volunteer observers. The Greenwich observers, Mr. JONES and Mr. DAVIDSON, will be stationed at Minsk. A party from the Solar Physics Observatory, consisting of Professor NEWALL, Mr. STRATTON, and Mr. BUTLER, will be located near Feodosia, near which spot will also be the camp of the expedition of the Cordoba Observatory under Dr. PERRINE. There will probably be a number of observers in Sweden and others near Riga. The Lick Observatory Crocker eclipse expedition, under Dr. CAMPBELL, with Dr. H. D. CURTIS as associate, will probably be located near the small town of Brovary about ten miles north east of Kiev, as near as possible to the central line. Dr. CAMPBELL will be accompanied by his family. The city of Hamburg is fitting out an expedition to be located at some point in Russia. An expedition headed by Professor

MIETHE of the Technological Institute of Charlottenburg will go to the island of Alsten on the Norwegian coast, where the path of totality first touches the European continent.

Excellent progress is being made in the preliminary work of the establishment of the Cawthron Observatory in New Zealand for work in solar physics and allied problems. Professor EVERSHED, of the observatory at Kodaikanal, has spent several months in New Zealand in consultation with the donor, Mr. CAWTHRON, as to the aims and equipment of the new observatory, and in investigating the various sites available. A site has not yet been definitely selected, but it will be at some elevation in the vicinity of Nelson. The need of such an observatory in the southern hemisphere has long been recognized, and the new Cawthron Observatory will fill a definite and useful field.

MINUTES OF THE MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN ROOM 2 OF THE STUDENTS' OBSERVATORY, BERKELEY, ON MARCH 28, 1914, AT 7:30 P. M.

There were present President CRAWFORD and Directors TOWNLEY, BURCKHALTER, CORNISH, BAIRD, and RICHARDSON.

The name of Mr. LUDWIG SCHWIERS, JR., was submitted for membership. Unanimously elected.

The Secretary read a letter from Professor WM. T. FOSTER, President of Reed College, Portland, Oregon, inviting members of the Astronomical Society of the Pacific to be the guests of Reed College at a dinner in Portland on the evening of May 20th, which entertainment was to be given in connection with the meeting of the Pacific Association of Scientific Societies in Seattle on May 21st. It was decided that no formal delegation would represent the Astronomical Society of the Pacific on that occasion, but a vote of thanks was extended to Professor FOSTER and the Faculty of Reed College for their courteous invitation.

The matter of inserting advertisements in the *Publications* of the Society came up for consideration and it was the opinion of those present that something might be done in that line to augment the revenues of the Society. The Secretary was instructed to look into the matter and ascertain if such action would impair in any way the right of our *Publication* to second-class postal rates.

The following minute was adopted in tribute to the memory of the late Professor EDWARD S. HOLDEN:—

EDWARD SINGLETON HOLDEN, who died on March 16, 1914, was the founder of the Astronomical Society of the Pacific, its first President, and the Chairman of its first Committee on Publication. To his organizing ability and his wise counsel, the Society owes not only its inception but also its rapid growth and its development into a definite force for the advancement of the science of astronomy. It was mainly at his suggestion that the funds for the Alexander Montgomery Library and for the Donohoe Comet-Medal were given to the Society, and it was due to his influence that Miss CATHERINE WOLF BRUCE made the Society the trustee for administering the Bruce Medal funds. The statutes governing the award of this medal, which have made the award one of the highest honors which an astronomer can receive, were originated by him. As long as his residence in California continued, he devoted time and thought earnestly and unselfishly to the promotion of the prosperity and influence of the Society.

In token of our gratitude for his devoted service, of our respect for his great ability, and of our sincere and deep regret at his death, we, the Directors of the Astronomical Society of the Pacific, enter this simple note upon our minutes.

We further direct that in future the List of Members of the Society be headed:

EDWARD SINGLETON HOLDEN, FOUNDER.

Adjourned.

D. S. RICHARDSON,
Secretary.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC IN THE ASSEMBLY HALL OF STUDENTS' OBSERVATORY, BERKELEY, ON MARCH 28, 1914, AT 8:00 P. M.

The meeting was called to order by President CRAWFORD, who introduced, as the speaker of the evening Dr. S D TOWNLEY, of Stanford, who delivered an instructive and exceedingly interesting address on the subject of "Some Recent Advances in the Study of Variable Stars"

At the close of the address the members present were invited to inspect the Bruce Gold Medal of the Society, which had just been received from the French Mint and duly engraved with the name of Professor O. BACKLUND, our medalist for the current year

Adjourned

D S RICHARDSON,
Secretary

OFFICERS OF THE SOCIETY

Mr. R. T. Crawford	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. S. D. Townley	*Second Vice-President*
Mr. C. S. Cushing	*Third Vice-President*
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Comet-Medal Committee—Messrs. W. W. Campbell, R. H. Tucker, and H. D. Curtis.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

PUBLICATIONS ISSUED BI-MONTHLY.

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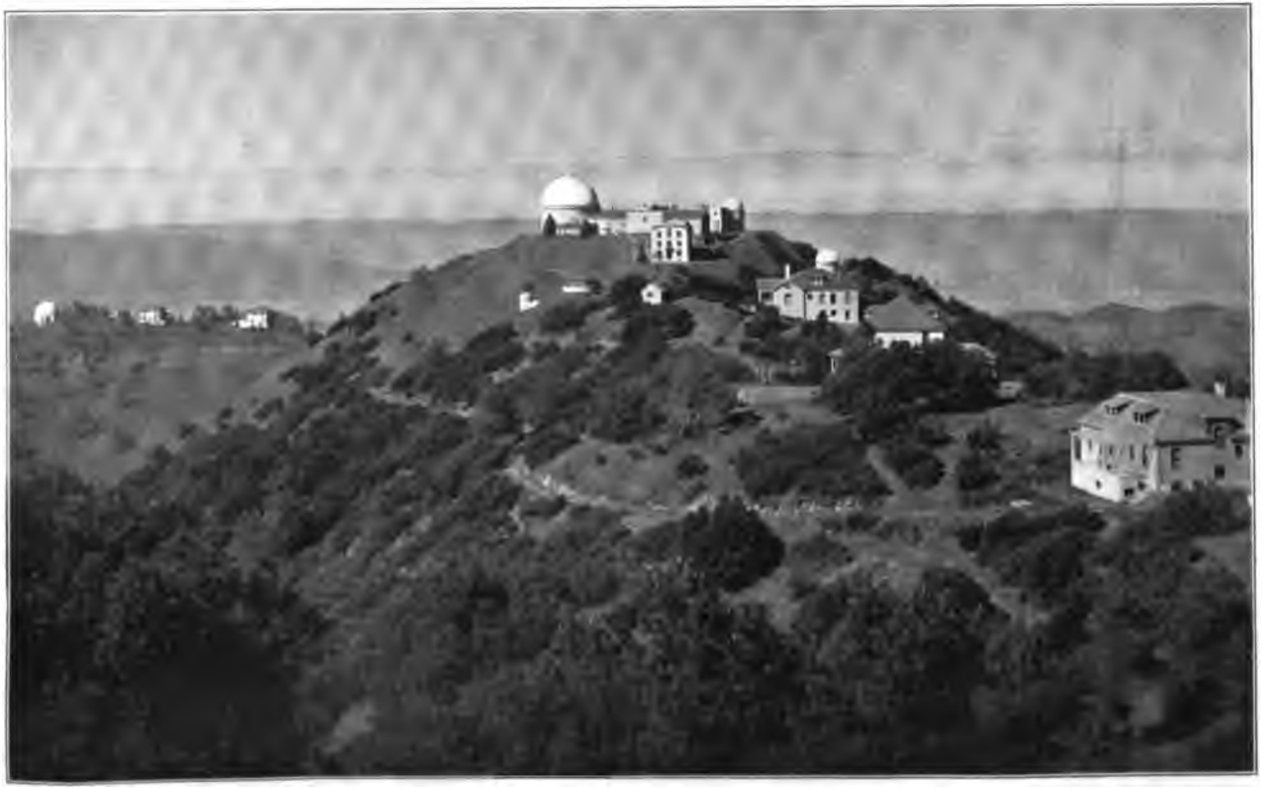

THE LICK OBSERVATORY FROM THE EAST, 1914.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

Vol. XXVI. San Francisco, California, June, 1914. No. [illegible]

THE ABSORPTION OF LIGHT IN SPACE

By J. H. [illegible]

It is the purpose of the present paper to call attention briefly to some of the evidence which has been presented by various investigators tending to show the existence of an appreciable absorption of light in passing thru interstellar space.

If it be granted that space is a perfect vacuum, that is, containing only the ether, then any diminution in the intensity of light in passing thru it must be due to the ether itself. Now it is assumed in the derivation of the equations of the electromagnetic theory that the ether is a perfect dielectric. The resulting expression for the velocity of propagation of an electromagnetic disturbance appears then in a form which is independent of the frequency. [illegible] waves of all frequencies would travel with the same [illegible]

[illegible]

absorption or a scattering of the light by small particles which would make its appearance as a selective absorption stronger for the blue than for the red rays.

At present we have no means of distinguishing as to which of these two media an absorption of light in space should be ascribed. It appears more probable, however, that it would be due to matter in some form in space rather than to the ether. In the present discussion we shall confine our attention to the question whether light suffers appreciable extinction in space apart from considerations of the medium by which it may be produced.

It is a well-known fact that a comparison of the number of stars of the successive orders of magnitude shows that the number corresponding to a given magnitude is approximately three times that belonging to the next brighter magnitude. Evidently this ratio of increase in number by magnitude cannot hold down to the very faint stars, for if it did, the sky would be a blaze of light. From a very careful enumeration of the number of stars by PICKERING[1] it is seen that this ratio decreases from 3.3 for the third to second-magnitude stars, to about 2.1 for that of thirteenth to twelfth magnitudes. That this decline in the rate of increase of the faint stars is due to the extinction of light of the fainter stars, which are on the average presumably the more distant, has been inferred by some.

A similar conclusion has been drawn by COMSTOCK[2] from his discussion of the mean parallax of stars of different magnitudes. On the hypothesis that the faint stars are of equal intrinsic brilliancy with the brighter ones, it follows from the known light ratio that a decrease of five magnitudes would correspond to a tenfold increase in distance. Taking the mean parallax of stars of magnitude 5.5, found by KAPTEYN, as $\pi = 0''.0158$, the mean parallax corresponding to magnitude 10.5, for example, should be $\pi = 0''.0016$. The value of the mean parallax for stars of magnitude 10.5 found by COMSTOCK is $\pi = 0''.0045$, almost three times that indicated by theory. He finds, however, that a good agreement between his determined mean parallaxes for different magnitudes and the computed values is given, when he introduces in his formula an absorption coefficient $a = 0.18$ magnitude. This coefficient of absorption a represents, in magnitude, the loss in brightness of a star when its light traverses the unit of distance of 32.6 light years, corresponding to a parallax $\pi = 0''.1$.

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[1] *H. C. O. Annals*, **48**, 149.

[2] *Astron. Jour.*, **24**, 43, 1904.

It must be remembered that the inferences of an extinction of light in space drawn above, from the number of stars of different magnitudes or from their mean parallax, are based implicitly upon either of two assumptions: (1) That all of the stars are equally bright, or (2) that they are equally distributed in space. The first of these is demonstrably false; the second is probably not true.

KAPTEYN[1] has derived the expression for the theoretical number of stars of a given magnitude and the value of their mean parallax, without introducing either of the above assumptions. From considerations of the proper motions of a large number of stars, together with other data, he has arrived at provisional values for the star density and magnitude curve on the tacit assumption that space is perfectly transparent. The number of stars of different magnitudes computed in this way is in good agreement with the number observed by PICKERING for each magnitude. Likewise, the mean parallaxes corresponding to different magnitudes deduced from his formula agree fully as well with the observed values as those computed by the formula of COMSTOCK on the assumption of an extinction of light in space. He does not conclude, however, that the above results show that there is no extinction of light. On the contrary he considers that they may be consistent with a small amount of absorption in space.

Upon what appears to be a reasonable hypothesis,—namely, that the intrinsically faint and bright stars are mixed in the same proportion at all distances from the Sun,—he computes the star density at different distances from us, which results from the assumption of different values of the coefficient of absorption a. For a value of $a = 0$ the star density decreases with increasing distance from the Sun, while for $a = 0.18$

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[1] *Astron. Journ.*, **24**, 115, 1904.

(COMSTOCK'S value) it increases rapidly as we proceed outward from the Sun. Either value of a assigns to the Sun a unique position in space, that of maximum or minimum star density. A value of $a = 0.016$ leads to practically a uniform distribution of the stars at different distances. KAPTEYN recognizes the provisional nature of the data from which this value of the coefficient of absorption is deduced and does not propose it for acceptance. He merely considers that there is some reason to believe that the average absorption must be of this order of magnitude.

If it can be shown that light waves of different frequencies travel with different velocities in interstellar space, we may at once infer that the medium in which this dispersion takes place will also produce absorption of the energy of these waves.

An attempt to detect the existence of dispersion of light in space has been made by two observers, NORDMANN[1] and TIKHOFF,[2] from observations of eclipsing variables. If the blue rays travel with a smaller velocity than the red ones, the time of minimum of an Algol variable determined from photometric observations in its blue light, should occur later than the minimum determined from like observations in its red light. It is evident that the determination of this time interval for an eclipsing variable whose distance from us is known would afford a method of determining the distances of other variable stars of this class, from observations of their time intervals between red and blue minima. NORDMANN'S method consisted in photometric observations of the variable made visually in succession thru three colored screens, each transmitting only one third of the visible spectrum—red, green and blue. For *Algol* he finds that the minimum when observed in blue light of wave-length 4300 A occurs about sixteen minutes later than when it is observed in red light of wave-length 6800 A. The time interval between the blue and red minimum for λ *Tauri* is about three times as great as that for *Algol*.

TIKOFF'S observations were made photographically, using colored gelatine filters for isolating the different regions of the spectrum. He found for RT *Persei* that the minimum observed in light of wave-length 4300 A occurred four minutes later than that observed in light of wave-length 5600 A. The retardation of the minimum for rays 3800 A with respect to that for orange light 6250 A was found to be about ten minutes for W *Ursæ Majoris*, a star showing continuous variation in light.

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[1] *C. R.*, **146**, 266 and 383, 1908.

[2] *C. R.*, **146**, 570, 1908; *ibid.* **148**, 266, 1909.

In the methods of NORDMANN and TIKOFF it is a question of observing the velocities of groups of waves and not those of individual waves. If the observed retardation of the blue with respect to the red rays be assumed to be due to dispersion of light in space, the observed retardation of the groups of waves must be divided by three in order to obtain the dispersion of this medium in the ordinary sense—that is, the dispersion of individual waves. In order to arrive at an idea of the amount of dispersion in space NORDMANN accepts a value of the parallax of *Algol* corresponding to a distance of sixty light years, while TIKOFF assumes that the distance of RT *Persei* is 740 light years.

LEBEDEW[1] calls attention to the fact that the results for space dispersion obtained by these two observers differ more than 30 to 1 and concludes "that a method which yields such widely different results for the same constant cannot be anything else than incorrect and therefore wholly inapplicable." He further points out that thru a medium producing an amount of dispersion found by NORDMANN and TIKOFF, no appreciable part of the light of the stars or even of the Sun, could reach the Earth. His objections to ether dispersion on the ground of the electro-magnetic theory are not well taken, for reasons stated earlier in this paper. It would appear that the discrepancy between the results obtained for space dispersion may, at least in part, be due to the very doubtful values of the parallaxes assumed for *Algol* and RT *Persei*. The method of monochromatic photometry, especially that used by NORDMANN, would seem to be adequate for detecting a time lag in the minima of *Algol* variables of the order found by these observers. It appears probable that the above results obtained for eclipsing variables are not to be explained by a dispersion of light in space, but are to be attributed rather to the peculiar physical properties of these stars.

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[1] *Aph. Jour.*, **29**, 101, 1909.

TIKOFF has brought forward another result as evidence of space dispersion, which is based upon data obtained by BELOPOLSKY and himself for the spectroscopic binary *β Aurigæ*. The spectra of both components are visible upon spectrograms of this star. From measures of plates secured in two regions of the spectrum—the blue (4420 to 4620 A) and the violet (3930 to 4100 A)—the epochs of coincidence of the lines of the two spectra were computed. He found that this epoch deduced from the spectrograms taken in the violet is delayed 0.015 days with reference to that obtained from the spectrograms secured in the blue region. An inspection of the data upon which this result is based shows, however, that little or no weight is to be attached to this observation.

From our knowledge of the phenomena of light in media with which we are familiar we should be led to infer that an absorption of light by a medium in interstellar space would be selective in that the blue rays would be affected more strongly than the red ones. As a result of space absorption of this nature it would follow that the more distant stars should appear redder than those nearer to us. Several methods of attacking this problem have been proposed, and it would appear that in some of these we have promise of finally obtaining an answer to the very difficult question whether light suffers absorption in space.

Now it is well known that the degree of redness of stars depends upon their type of spectrum; that is, upon the physical constitution of the atmosphere of these stars. In comparing the redness of stars at different distances it is essential, then, that the stars observed be of exactly the same spectral type.

KAPTEYN[1] has called attention to the fact that in the classification of stellar spectra Miss MAURY has divided those of Class XVa into two groups, of which the spectrum of *a Bootis* is characteristic of one division and that of *a Cassiopeiæ* of the other. The spectra of stars of the *a Bootis* division show slight general absorption in the violet, while for those of the α *Cassiopeiæ* group the absorption in the violet is more conspicuous and to the violet of 3889 A their spectra are suddenly cut off. We appear to have here stars of the same spectral type which differ only in the amount of the absorption of their violet rays. If this difference be due to selective space absorption, we should expect to find the stars of the α *Cassiopeiæ* group to be the more distant.

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[1] *Aph. Jour.*, **29**, 46, 1909.

From a discussion of the available proper motions of the twenty-five stars of the α *Bootis* division and of the forty-five of the α *Cassiopeiæ* group, KAPTEYN finds:—

	α *Cassiopeiæ* division.	α *Bootis* division.
Number of stars of centennial proper motion < 10″	58%	20%
Number of stars of centennial proper motion > 30″	0%	48%

On the assumption that the stars having small proper-motions are on the average more distant than those with large proper-motions, the above evidence would point to the conclusion that the stars of the α *Cassiopeiæ* group are in general more distant than those of the α *Bootis* division. Evidence is thus afforded by the stars in question that the violet portion of their spectrum is relatively fainter for those stars which are the more distant. Inasmuch as the average apparent magnitude of the stars of the two groups is about the same, the luminosity of the stars of the more distant α *Cassiopeiæ* group must be greater than that of the α *Bootis* division. KAPTEYN points out that the above result does not necessarily indicate a selective absorption of the violet light in space, but may mean that for stars of the same spectral type the light of the more luminous objects is relatively weaker in the violet part of the spectrum.

An investigation which is in principle the same as the one just cited is being conducted by Mr. ADAMS[1] with a one-prism spectrograph attached to the 60-inch reflector at Mount Wilson. His method consists in photographing upon the same plate the spectra of two stars which are of exactly the same spectral type, one of which is known to be near to us and the other, from its small proper-motion, presumed to be distant. A comparison of the relative intensities of the two spectra at 5000 A and 4200 A for a few pairs of stars showed that on most of the plates the spectrum of the star presumed to be the more distant was relatively weaker in the violet than that of the star of large proper-motion. Some pairs showed little or no difference, but in no case was the spectrum of the star of small proper-motion stronger in the violet. More recently[1] he has attempted to utilize the large number of radial-velocity spectrograms secured at Mount Wilson for the same purpose. These were compared with a standard plate of α *Tauri* on the spectrocomparator and estimates of their relative intensity at 4549 A and 4220 A were made. As a result of this discussion he finds that: (1) The violet end of the spectrum of stars of small proper-motions is decidedly weaker than for those of large proper motions; (2) this difference is less for Class F stars and increases with the spectral type at least as far as Class K stars. As the average proper-motions of the different groups of stars of Classes F to K used in the discussion are so nearly the same, it seems probable that at least part of the observed difference in the absorption of the violet rays is due to physical differences in the stellar atmospheres.

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[1] *Ap. Jour.*, 39, 89, 1914.

As mentioned above, the stars assumed to be more distant in making these comparisons must in general be the more luminous, and presumably larger than those considered to be near us. That the atmosphere of a large massive star would show greater selective absorption for violet light than that of a small and less massive one seems reasonable from physical considerations. In order to ascribe the observed difference in the absorption of the violet rays to a selective absorption in space it will be necessary to show that it is not due to the cause just cited—that is, to what KAPTEYN calls the effect of absolute magnitude. A comparison of the relative intensities of stars of the same spectral type which are known to be at about the same distance from us, but which differ greatly in absolute magnitude, would undoubtedly throw some light upon this question. The components of some visual binaries should satisfy these conditions.

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[1] *Publ A. S. P.*, **26**, 90, 1914.

An effort has been made by KAPTEYN[1] to obtain some quantitative determination of the space absorption by taking, as a measure of the degree of redness of the stars, the difference between the photographic and visual magnitudes, and as a measure of average distance the apparent magnitudes and proper motions of these stars. The discussion is based upon 1,433 stars whose photographic magnitudes are taken from the Draper Catalog and the visual magnitudes from the Harvard Revision. He puts,—

$$\text{Photo. Mag.} - \text{Vis. Mag.} = a + b\,m + c\,M + d\,\Delta,$$

where Δ is equal to unit distance of 32.6 light years, and m and M are the apparent and absolute magnitudes, respectively. The constant a is dependent upon the class of spectrum, b is the change of redness per unit of apparent magnitude, c the change of redness per unit of absolute magnitude, and d the increase of redness per unit of distance. He proceeds then to determine the values of these constants from all the available data.

Some difficulty is experienced in the derivation of c as the data are sufficient to give only a good determination of $d - 0.25\,c$. From the value of c, which he finally derives on certain assumptions, he finds that $d = 0.0031 \pm 0.0006$ mag. This value of d would correspond to a loss of light for a distance of 32.6 light years, for the visual rays of 0.0028 magnitude and for the blue rays of 0.0057 magnitude. He finds, moreover, that there is no evidence of a difference of absorption in different directions in space.

Mr. KING[2] has applied the same method to a discussion of his photometric observations for twenty-six stars. The constant a was eliminated by using the deviations of the difference photo.mag — visual mag. for each star from the mean of its class of spectrum. To eliminate b a grouping of the deviations for 150 stars was made with respect to the magnitude, and the small corrections thus obtained were applied to the deviations of the twenty-six stars. He finds $d = 0.019 \pm 0.010$ magnitude, indicating a loss of 0.0377 magnitude for the photographic rays, and 0.0184 magnitude for the visual rays, while traversing the distance of 32.6 light years. More recently[1] he has combined the results for the above twenty-six stars and those for twenty-two additional ones. By selecting from these the twenty-five stars whose parallaxes are based upon the work of two observers, he obtains $d = 0.0189 \pm 0.0065$ magnitude, a value which is practically identical with that previously found. The value of the loss of light per unit distance found by him is more than six times that derived by KAPTEYN from his similar discussion. It is of interest to note that his value for the loss in the visual rays, of 0.018 magnitude, is in good agreement with that which KAPTEYN regards as a probable value from his discussion of the distribution of the stars referred to above—namely, 0.016 magnitude.

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[1] *Aph Jour.* **30**, 284, 1909.
[2] *H. C. O. Annals*, **59**, 179, 1912.

The evidence that the faint stars are appreciably redder than the bright ones is accumulating from photometric and spectroscopic observations. One of the most recent contributions is that of HERTZSPRUNG.[2] He has photographed numerous regions with a large grating attached to the tube of the 60-inch reflector at Mount Wilson for the purpose of determining the effective wave-lengths of the light of the faint stars. On his plates of the field containing the cluster N. G. C. 1647 he finds that from the ninth magnitude on there is a gradual increase in the effective wave-length, indicating that the fainter stars are redder than the brighter ones.

To sum up the results to which we have referred concerning the degree of redness of the stars, existing evidence strongly indicates the reality of the two following phenomena:—

(1) Apparent magnitudes and spectral lines being the same, the stars are redder the more distant they are from us.

(2) On the average, the fainter stars are redder than the brighter ones.

Whether or not the explanation of these phenomena be selective absorption of the violet rays, it is impossible to say from our present knowledge, altho it seems probable that absorption of light in space may play at least some part in their production. Whatever their explanation, these two phenomena are of the greatest importance.

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[1] *H. C. O. Annals*, **76**, 1.

[2] Annual Report of the Director of the Mount Wilson Solar Observatory, Year Book of the Carnegie Institution, No. 12.

An attempt has been made to throw some light upon the question of the existence of space absorption from still another point of attack by Mr. F. G. BROWN.[1] His method consists in comparing the average brightness of the nebulæ of different diameters, on the assumption that on the average the objects with a small apparent diameter must be more distant than the larger objects. If there were no absorption of light in space the intrinsic brightness of a nebula would be the same whatever is its distance from us. If the light is partly absorbed, the average brightness of the smaller objects would be less than that of the larger ones. The data upon which he bases his discussion is derived from the descriptions contained in the *New General Catalogue*. It must be said that even with the very unreliable data which he had at hand, the results show a marked decrease in average brightness of the nebulæ with decreasing diameter. It would seem that the method would be capable of yielding results of importance if reliable photometric and micrometric measures of a large number of nebulæ were available.

In reviewing the evidence which has been deduced in favor of an absorption of light in interstellar space, it appears that the individual results obtained by any one of the above methods, while they may be explained on the assumption of a small amount of space absorption, do not point conclusively to this as the true explanation. However, the fact that we have been led to the same indication of an absorption of light in space by several different methods based on different assumptions lends some probability to its existence.

May, 1914.

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[1] *Monthly Notices R. A. S.*, **72**, 195 and 718.

THE GALACTIC STAR CATALOG AND TABLES PROPOSED BY INNES.

By G. F. Paddock.

CATALOG AND FORMULÆ.

The essential principle for a permanent star catalog must be a system of invariable co-ordinates. The equatorial co-ordinates which have always been used are continually changing because of precession of the equinox. A natural system would be one related to the natural features of the stellar system. Mr. Innes proposes for the fundamental plane the one suggested by the peculiar configuration of the stars, the Milky Way, and for the zero point of longitude, the longitude of the apex of the Sun's motion. He has presented in the South African Union Observatory *Circulars*[1] the reasons for, and advantages of, the galactic system of star places, with the necessary reduction formulæ and tables and examples of their use. Since the reference system for the stars is a matter of essential importance in the practical use of star catalogs and the study of the stellar universe, a concise synopsis of the formulæ, an illustration of the proposed catalog in galactic co-ordinates, and a brief discussion of the theme is here presented. Illustrations of the tables and computations cannot be conveniently included here, but may be found in Mr. Innes's papers.

A star catalog in galactic co-ordinates would contain in successive columns the star's name or designation, magnitude, spectrum, galactic longitude (λ), centennial proper-motion in longitude, galactic latitude (β), centennial proper-motion in latitude, right ascension (α) plus centennial precession, declination (δ) plus centennial precession, and finally the authority for the given co-ordinates. A short catalog is given below for illustration. The values of λ and β are given with full accuracy, but α and δ are given only to tenths of a minute of time for α and to the minute of arc for δ. These approximate α's and δ's are sufficient for use at the telescope and by means of the adjoined values of precession they suffice for identifications at different epochs.

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[1] Numbers 2, 5, 6, 9, 10; 1912, 1913.

The formula for the conversion of observed right ascensions and declinations into galactic longitudes and latitudes for the catalog are:—

$$\begin{aligned}
\cos\beta\cos(\lambda + D) &= \cos\delta\cos(\alpha - \text{☊}) \\
\cos\beta\sin(\lambda + D) &= \cos\delta\sin(\alpha - \text{☊})\cos\iota + \sin\delta\sin\iota \\
\sin\beta &= -\cos\delta\sin(\alpha - \text{☊})\sin\iota + \sin\delta\cos\iota
\end{aligned}$$

in which

☊ = right ascension of the ascending node of the galactic plane,
ι = inclination of the galactic plane to the equator,
D = angle between node and zero point of longitude.

The zero point of longitude is assumed to be at the meridian of longitude passing thru the solar apex. For finding α and δ from the catalog place, the formulæ are:—

$$\begin{aligned}
\cos\delta\cos(\alpha - \text{☊}) &= \cos\beta\cos(\lambda + D) \\
\cos\delta\sin(\alpha - \text{☊}) &= \cos\beta\sin(\lambda + D)\cos\iota - \sin\beta\sin\iota \\
\sin\delta &= \cos\beta\sin(\lambda + D)\sin\iota + \sin\beta\cos\iota
\end{aligned}$$

The solution of these formulæ may be performed by means of auxiliary angles, as shown in text-books on practical and spherical astronomy, or more conveniently and precisely by direct computation with the help of ZECH's addition and subtraction logarithms. To obtain quickly from λ and β the approximate α and δ for use at the telescope, a table may be formed in which precession factors are given similarly, as shown below in the catalog. It may not be a convenient form for the reverse operation, and a reverse table would be of use for only a few years. However, rapid computation of λ and β from α and δ may be effected with the help of a table in connection with the following formulæ, which connect the co-ordinates α, δ, λ, β of the star with those, α, δ_0, λ_0, $\beta = 0$, of the point of intersection of the star's declination arc with the galactic plane:—

$$\begin{aligned}
\sin\eta_0 &= \cos(\alpha - \text{☊})\sin\iota \\
\tan(\lambda_0 + D) &= \tan(\alpha - \text{☊})\sec\iota \\
\tan\delta_0 &= \sin(\alpha - \text{☊})\tan\iota \\
\tan\alpha_2 &= \sin\eta_0\tan(\delta - \delta_0) \\
\tan\eta &= \tan\eta_0\sec(\delta - \delta_0) \\
\tan\beta &= \cos\eta\tan(\delta - \delta_0) \\
\sin\beta &= \cos\eta_0\sin(\delta - \delta_0) \\
\lambda &= \lambda_0 + \alpha_2 = \alpha + \alpha_1 + \alpha_2
\end{aligned}$$

in which

η = parallactic angle at the star with respect to the north pole and galactic pole,
η_0 = parallactic angle at λ_0, $\beta = 0$, with respect to the north pole and galactic pole,
a_2 = arc of longitude between the star's declination arc and latitude arc,
$a_1 = \lambda_0 - a$,

where the

quadrant of a_2 is same as that of $(\delta - \delta_0)$ when η_0 is +,
quadrant of a_2 is same as that of $-(\delta - \delta_0)$ when η_0 is —,
quadrant of η is first or fourth according to sign, + or —, of $\tan \eta_0 \sec (\delta - \delta_0)$.

If now η_0, λ_0, and δ_0 are tabulated with right ascension as argument, then λ and β are found by a very short calculation. Mr. INNES has constructed a 12-hour table giving to four places of logarithms and tenths of a minute of arc, the values of $\log \sin \eta_0$, $\log \tan \eta_0$, δ_0, a_1, for each hour and minute of right ascension for the mean equinox of 1900. If a exceeds 12 hours, the table may be used with $a - 12^h$, finally adding 180° to λ and changing the signs of η and β. The resulting λ and β are found to the nearest minute of arc which is sufficient for many uses of galactic co-ordinates.

The determination of the elements of the galactic plane for any epoch takes the place of the work of reducing equatorial co-ordinates of different epochs to the same epoch, and must precede the conversion of co-ordinates to and from galactic co-ordinates. The elements are ☊, ι, D, which are defined above. Taking as the fundamental galactic plane that determined by NEWCOMB for 1900 and as the place of the solar apex that adopted by CAMPBELL (assumed to be for 1900), we have for the—

Galactic pole, $a = 191°.1$, $\delta = +26°.8$,

and for the

Sun's apex, $a = 270°$, $\delta = +30°$.

Whence

$$\begin{aligned} 1900\ ☊ &= 281°\ \ 6'\ \ 0''.00 \\ 1900\ \iota &= 63\ \ 12\ \ 0\ .00 \\ 1900\ D &= 23\ \ 35\ \ 27\ .26 \end{aligned}$$

From NEWCOMB's value of the precession of the equinox, etc., Ω, ι, D, may be found for the epochs and, by interpolation, for the beginning of any year from the formulæ:—

$$\begin{aligned} \Omega &= 281^\circ\ 6'\ 0''.00 + 4413''.57\,T - 6''.88\,T^2 + 0''.186\,T^3 \\ \iota &= 63\ \ 12\ \ 0\ .00 + 1967\ .18\,T - 4\ .56\,T^2 - 0\ .145\,T^3 \\ D &= 23\ \ 35\ \ 27\ .26 + 432\ .40\,T + 22\ .46\,T^2 - 0\ .128\,T^3 \end{aligned}$$

in which $T =$ solar centuries from 1900. Mr. INNES has tabulated these values for five-year intervals from 1750 to 1950 and for every year from 1900 to 1925.

A ten-day ephemeris of Ω, ι, D for any year may be constructed by means of the formulæ:—

$$\begin{aligned} \Omega_1 &= \Omega + f - g \cos(G + \Omega) \cot \iota \\ \iota_1 &= \iota \quad\ \ - g \sin(G + \Omega) \\ D_1 &= D \quad + g \cos(G + \Omega) \operatorname{cosec} \iota \end{aligned}$$

in which f, g, G are star-numbers given in the Nautical Almanacs. From this ephemeris Ω_1, ι_1, D_1, may be taken for any day of the year and with Ω_1, ι_1, D_1, the apparent place in right ascension and declination may be derived by a single computation. Thus is eliminated the reduction to apparent place which is usual in equatorial co-ordinates. Mr. INNES has constructed an ephemeris for 1913 and 1914, which gives, for greater convenience, the values of log sin ι and log cos ι in place of ι.

A ten-day ephemeris of aberration factors for the aberrational displacements in longitude and latitude may be constructed from the following formulæ:—

$$\begin{aligned} \Omega_2 &= 208^\circ\ 34'\ 28''.27 + 5051''.40\,T + 1''.15\,T^2 \\ \iota_2 &= 61\ \ 10\ \ 56\ .83 + 3\ .84\,T + 0\ .21\,T^2 \\ D_2 &= 50\ \ \ 3\ \ 42\ .04 - 53\ .65\,T - 0\ .01\,T^2 \\ h \sin H' &= -\mathrm{K} \cos \iota_2 \cos(\odot - \Omega_2) \\ h \cos H' &= -\mathrm{K} \sin(\odot - \Omega_2) \\ -i &= -\mathrm{K} \sin \iota_2 \cos(\odot - \Omega_2) \\ H &= H' + D_2 \\ \Delta\lambda &= h \sin(H + \lambda) \sec \beta \\ \Delta\beta &= h \cos(H + \lambda) \sin \beta + i \cos \beta \end{aligned}$$

in which

K = constant of aberration
$\odot$ = Sun's longitude
$\Delta\lambda$ = aberrational displacement in longitude
$\Delta\beta$ = aberrational displacement in latitude

while Ω_2, ι_2, D_2 are the elements of the galactic plane with respect to the ecliptic, and h, H, i, are numbers which may be tabulated like BESSEL's star-numbers. Mr. INNES has named the quantities h, H, log i, Ω, D, log sin ι, log cos ι (omitting the subscript), galactic day-numbers, and gives a table of them for 1913 and 1914.

A ten-day ephemeris of the right ascension and declinations of any star may be constructed by the following differential method, which avoids the repeated seven-figure calculation of conversion for each date. The method requires the right ascension and declination of the star for a single date within the interval of the ephemeris and computed with the corresponding values of λ, β, D, Ω, ι. This is most conveniently taken at the middle point of the interval; for instance, June 30th for a year's ephemeris. The differences $\Delta\alpha$ and $\Delta\delta$ for each tenth day of the year are then computed by the following formulæ:—

$$\Delta\alpha = c\,\mathrm{C} + d\,\mathrm{D} + e\,\mathrm{E} + \mathrm{F}$$
$$\Delta\delta = c'\mathrm{C} + d'\mathrm{D} + e'\mathrm{E}$$

$$\begin{array}{l|l}
a = \cos(\lambda + D_2)\sec\beta & a' = -\sin(\lambda + D_2)\sin\beta - \tan \quad \beta \\
b = \sin(\lambda + D_2)\sec\beta & b' = \cos(\lambda + D_2)\sin\beta \\
c = \cos\eta\cos\beta\sec\beta & c' = \sin\eta\cos\beta \\
d = -\sin\eta\sec\delta & d' = \cos\eta \\
e = -\tan\delta\sec(\alpha - \Omega) & e' = \sin(\alpha - \Omega)
\end{array}$$

$$\begin{array}{ll}
\mathrm{A} = -[0.9942]\cos(\odot - \Omega_2) & \mathrm{C} = \Delta\lambda + \Delta D + \mu_\lambda \\
\mathrm{B} = -[1.3111]\sin(\odot - \Omega_2) & \mathrm{D} = \Delta\beta + \mu_\beta \\
\Delta\lambda = a\,\mathrm{A} + b\,\mathrm{B} & \mathrm{E} = \Delta\iota \\
\Delta\beta = a'\mathrm{A} + b'\mathrm{B} & \mathrm{F} = \Delta\Omega
\end{array}$$

in which a, a', b, b', c, c', d, d', c, c' are star-numbers in the galactic system, and log A, log β, ΔD, E, F are day-numbers, which may be tabulated in a ten-day ephemeris and given in the astronomical almanacs. η is the parallactic angle and μ_λ and μ_β are the proper motions, while $\Delta\lambda$ and $\Delta\beta$ are as before the reductions for aberration. Mr. INNES has constructed the ephemeris of day-numbers for 1913 and 1914 and an ephemeris for ϵ *Orionis* for 1913.

CATALOG IN GALACTIC CO-ORDINATES.

Star	Mag.	Spect.	λ	μ_λ	β	μ_β	α 1900 + T	δ 1900 + T	Authority
			° ′ ″	″	° ′ ″	″	h m m	° ′ ″	
31 *Comæ*	5.1	G2	43 48 2.06	+ 75.40	+ 88 36 24.38	+ 3.37	12 46.8 + 4.9	+ 28 5 − 33	Newcomb
Parissima	9.3	..	66 19 15.26	+ 3.26	+ 26 53 22.87	+ 0.30	15 29.4 −172.6	+ 89 53 − 31	Courvoisier
Polaris	2.1	F8	66 38 3.53	+ 4.55	+ 25 35 26.88	+ 0.80	1 22.6 + 67.2	+ 88 46 + 30	Newcomb
α *Persei*	1.9	F5	90 14 39.72	+ 4.00	− 6 28 6.25	− 0.71	3 17.2 + 7.2	+ 49 30 + 21	Newcomb
κ *Persei*	4.0	K	90 52 23.45	+ 22.60	− 12 1 44.38	− 5.32	3 2.7 + 6.7	+ 44 29 + 23	Gr. 1900 II
Aldebaran	1.1	K5	121 55 29.89	+ 20.41	− 20 17 52.28	− 6.12	4 30.2 + 6.7	+ 16 19 + 12	Newcomb
ε *Orionis*	1.8	B	149 5 17.46	− 0.11	− 16 52 50.86	+ 0.04	5 31.1 + 5.1	− 1 16 + 4	Newcomb
9 *Puppis*	5.3	F8	175 46 26.06	+ 24.92	+ 7 22 5.08	−25.01	7 47.1 + 4.6	− 13 38 − 15	Gr. 1900 II
Archernar	0.6	B5	233 58 43.09	− 11.79	− 57 50 20.05	+ 6.77	1 34.0 + 3.7	− 57 45 + 30	Newcomb
Brisbane 3574	7.8	..	236 25 40.42	− 50.40	+ 0 27 16.41	− 9.30	11 20.3 + 4.4	− 61 6 − 33	Circ. No. 6
P G C. 4448	5.6	A	317 38 43.07	− 1.98	+ 11 13 54.68	− 3.29	17 29.2 + 5.6	− 11 10 − 4	Boss
P G. C. 4412	7.8	..	317 56 46.47	− 3.27	+ 14 28 34.89	+ 2.76	17 18.5 + 5.5	− 9 16 − 6	Boss
μ *Ophiuchi*	4.6	B8	320 48 5.86	− 2.45	+ 12 6 52.19	− 0.85	17 32.4 + 5.4	− 8 3 − 4	Boss
P G. C 4423	4.6	F	322 7 53.21	− 5.21	+ 16 1 22.52	+ 5.61	17 21.3 + 5.3	− 5 0 − 5	Boss
P. G. C. 4442	5.7	A	322 23 46.06	− 11.09	+ 14 12 41.22	− 1.11	17 28.2 + 5.3	− 5 40 − 5	Boss
4 *Aquilæ*	5.0	B5	337 38 14.83	− 1.76	+ 1 54 43.94	− 1.39	18 39.8 + 5.0	+ 1 57 + 6	Boss

The effect of the solar motion is well shown here in the tendency of the proper-motions in longitude to change sign towards the anti-apex.

DISCUSSION.

The natural plane for the stars is the galactic plane, instead of the continually shifting Earth's equator and equinox, whose motions complicate all work and investigation unnecessarily. The work of conversion of co-ordinates Mr. INNES shows to be comparatively simple and not much different from that of reducing a star-place from the beginning of the year to date, while reduction from epoch to epoch is never required in the galactic system.

The advantages of galactic catalogs and co-ordinates are concisely these: Reductions to date require less work than the present system. All catalogs, whatever their epoch, will be comparable, since differences of star-places will be caused only by proper-motion. Proper-motions and facts of stellar distribution and drift appear directly from the catalogs.

Precise equatorial co-ordinates will always be required, first, for about three hundred standard stars or clock and fundamentals stars for observations of Sun, Moon, and planets, etc.; second, for six to twelve thousand reference stars for the astrographic charts, equatorial comparison stars for comets, etc., and latitude variation. The remainder of the seven and a half million star-places which will ultimately be contained in the astrographic catalogs will never be required in equatorial co-ordinates. The unvarying galactic co-ordinates are consequently more proper and advantageous for the general star catalogs.

The adoption of galactic co-ordinates will facilitate the inversion of the present method of determining proper motions. In the comparison of charts of different epochs the original bright stars of reference will not be fundamental, but instead, the totality of faint stars whose proper motions are small. The proper-motions of the brighter stars will be determined from the faint stars and not from other bright stars. The work of BURNHAM, BARNARD and others indicates in general the almost absolute fixity of the very faint stars.

Permanent photographic regions are not possible when defined with respect to the equator and equinox. But with the introduction of the galactic system the sky may be divided into about eight hundred overlapping areas of about sixty square degrees each, whose centers at different epochs will remain the same with respect to the stars and co-ordinates. The same stars will be found on corresponding plates of all epochs. These galactic areas might finally replace the old constellations.

A permanent or uniform numbering system for the stars is not possible for the present astrographic areas and catalogs whose numbers follow different systems. A star cannot be effectively defined by its astrographic number. With the introduction of permanent galactic regions and by limiting designations to generally useful stars, seven to nine stars conspicuous in each square degree could be selected for designation. In this way nearly a half million stars practically uniformly distributed over the sky would receive permanent numbers. The remaining seven million cataloged stars need not be further defined than by their galactic co-ordinates. An example of the designation of a star would be 325, 8, 8, signifying star No. 8 in the square of galactic longitude 325° and latitude 8°. North and south latitudes could be distinguished by italics.

In the application of galactic co-ordinates to the astrographic catalog the formulæ are changed only by writing λ and β for α and δ and L and B as the galactic co-ordinates of the center of the plate. The computation of the equatorial place of a star from an astrographic catalog in galactic standard co-ordinates would require the computation of λ and β by the above-mentioned formulæ and then the conversion of λ and β to α and δ for the given date. The computation of precession from the epoch of the present astrographic catalogs to the beginning of the given year would not enter the process in galactic co-ordinates. Galactic standard co-ordinates would thus offer great advantage for the astrographic catalogs. If the astrographic chart and catalog is repeated in the future on the equatorial system the comparison of the catalogs will be an enormous piece of work and expense. It is to be hoped that the future chart and catalog will be planned on the basis and system outlined by Mr. INNES. The real value of the present astrographic work will lie not in its catalogs, but in its charts, which may be compared with future charts by superposition.

The use of galactic co-ordinates for planetary theories would result in a great saving of work, principally the reductions to an adopted equinox and the conversions to ecliptic longitude and latitude. The orbit constants would remain constant for centuries, changing only because of perturbations.

The objection to galactic co-ordinates that they cannot be of use for observing purposes at the telescope or for immediate identifications is offset by including in the galactic catalog the approximate right ascension and declination with the annual precession. The indefiniteness of the galactic circle and uncertainty of the Sun's apex have been mentioned as difficulties in establishing the galactic system. The positions of the galactic plane and departure point of longitude would be somewhat arbitrary and it might be difficult for astronomers to agree on these points. But future determinations of the plane and apex will differ but little from those that may now be adopted and will cause no inconvenience. Attention has been called to the necessity of continued work with the meridian instruments on the standard stars and the unnecessary labor of conversion to galactic co-ordinates. But the standard star catalog and annual ephemerides would still be constructed in equatorial co-ordinates, as pointed out above, for the few thousand standard and reference stars required. The transition from the equatorial system to the galactic system and the difference between the present and the future catalogs would of course cause difficulties, but these and others would probably not be paramount to the ultimate advantages of the galactic system. The impression that the use of galactic co-ordinates would lead to formulæ of greater complexity than those given by BESSEL is herewith removed by Mr. INNES's presentation of the application of the system. The formulæ and computations are in general shorter. This constitutes a considerable gain, "but the real gain is beyond this. Star-places in galactic co-ordinates are final and comparisons between catalogs become immediate. The deduction of a proper motion to-day requires hours or days of work because of the fictitious movements of the co-ordinate system. With galactic co-ordinates the comparison will be the work of minutes, while yielding proper-motion referred to its natural plane."

A SUGGESTED METHOD FOR ELIMINATING THE EFFECTS OF VARYING TRANSPARENCY OF THE AIR AND OF POSSIBLE VARIABILITY OF COMPARISON STARS IN SENSITIVE PHOTOMETRIC OBSERVATIONS.

By C. D. Perrine.

The wonderful accuracy obtained in the first experiments with the new photo-electric cell opens up an entirely new field of possibilities. At the same time such accuracy points to the necessity of taking precautions to eliminate small sources of error which heretofore have been neglected.

It has been for a long time common suspicion that sufficiently sensitive methods might reveal slight fluctuations in most of the heavenly bodies. It may be that the new cell is sensitive enough to make the finding of comparison stars which are sufficiently invariable in brightness, difficult or perhaps practically impossible.

This difficulty could, to a great extent, at least be overcome by using a number of comparison stars and depending upon the mean to be constant.

There is, however, a method which I think can be used to eliminate at once errors of the above nature and also variations of transparency of the air, and with little extra work.

If we integrate the light from a considerable area of stars and sky (say of one-half degree or more in diameter according to the requirements of the case), we should have a very constant source of comparison. Such a source should also eliminate variations in the transparency of the atmosphere.

The simplest and best method of integration would seem to be to project the region of sky (either in focus or out-of-focus) directly upon the sensitive surface of the cell when this can be done. For very large regions of sky this might be difficult.

In such cases very short focus lenses or mirrors might be used for standardizing. In fact, it seems probable that for such purpose entirely auxiliary apparatus may be found most satisfactory.

Observatorio Nacional Argentino,
Córdoba, February 8, 1914.

PLANETARY PHENOMENA FOR JULY AND AUGUST, 1914.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon	July 7,	$6^h\ 0^m$ A.M.	Full Moon	Aug. 5,	$4^h\ 41^m$ P.M.
Last Quarter..	" 14,	11 32 P.M.	Last Quarter ..	" 13,	4 56 P.M.
New Moon. ..	" 22,	6 38 P.M.	New Moon ...	" 21,	4 26 A.M.
First Quarter...	" 29,	3 51 P.M.	First Quarter .	" 27,	8 52 P.M.

The third eclipse of the year will be a total eclipse of the Sun, occurring August 21st. The regions traversed by the line of totality extend from the Arctic Ocean north of British North America, nearly eastward thru northern Greenland, Norway, Sweden, thence southeast thru the Baltic, Russia, the Black Sea, and Persia, ending in the northwestern part of India. The maximum duration of totality will be in Russia, where it will last not quite two and one-quarter minutes, rather a small duration, but the path is accessible. The eclipse may be seen as partial in the eastern part of the United States and Canada during the early morning.

The Earth reaches aphelion, its farthest distance from the Sun on July 2d, 4 P. M. Pacific time.

Mercury is an evening star on July 1st, setting a little more than an hour after sunset, and may be seen in the evening twilight under good weather conditions, but its distance from the Sun is growing smaller and it passes inferior conjunction on July 16th. It is then a morning star until it reaches superior conjunction on August 30th. Its maximum distance from the Sun is reached on August 5th, rather a small greatest elongation, 19° 14′, as the time is only eleven days before perihelion passage. During the first half of August the planet will rise about an hour and a quarter before the Sun, and will therefore not be a difficult object to see when the western sky is clear during evening twilight.

Venus is the most prominent object except the Moon in the western sky during the evenings of July and August. On July 1st it remains above the horizon a little more than two hours after sunset, and the interval shortens to about an hour and three quarters by the end of August. This shortening up of the interval between the setting of the Sun and of the planet is not due to a lessening of the apparent distance between the objects; in fact, the distance increases by about 5° during the two months, but because the planet's apparent position is increasingly south of that of the Sun. On July 1st *Venus* is 5° south of the Sun and on August 31st it is 19° south. On July 13th it passes about 1° south of *Regulus*, α *Leonis*, and on August 31st less than 1° north of *Spica*, α *Virginis*. On August 5th, 6 P. M. Pacific time, it is in very close conjunction with *Mars*, being only 10′ south. *Venus* is now much brighter than it was in the early spring, but will not reach its maximum until toward the end of October.

Mars is still an evening star, but its apparent distance from the Sun is continually diminishing. On July 1st it sets at about half-after ten and on August 31st at a little before 8 P. M. It moves 35° eastward and 16° southward from *Leo* into *Virgo*. On August 8th it makes a very close approach to the fourth-magnitude star β *Virginis*, and on August 30th it passes very close to the third-magnitude star γ *Virginis*. Its conjunction with *Venus* on August 5th has been previously mentioned. It is still growing fainter, altho at a less rapid rate than during the early part of the year, and its brightness at the end of August is only about one fourteenth as great as it was at the time of opposition in January. Its distance from the Earth increases from 187,000,000 to 217,000,000 miles during the two months.

Jupiter rises before 10 P. M. on July 1st and an hour before sunset at the end of August. It comes to opposition on August 10th and is then above the horizon thruout the entire night. It is in the constellation *Capricorn* and moves 7° westward and 2 southward during the two months. The Moon passes very close to the planet on the south on the night of July 9th-10th and again on the night of August 5th-6th. For some points in the southern hemisphere the planet will be occulted on both occasions.

Saturn passed conjunction with the Sun on June 13th and is now a morning star. On July 1st it rises a little less than an hour before sunrise, and on August 31st shortly after midnight. It is in the eartern part of *Taurus* and moves about 7° eastward nearly to the border of *Gemini* during the two months. As seen in the telescope, the rings present about the same appearance as they did earlier in the year, the apparent minor axis being about 44 per cent of the major.

Uranus rises at about half-after nine on July 1st, and on August 2d comes to opposition with the Sun, rising at sunset. At the end of August it will be above the horizon until about 3 A. M. It is in the constellation *Capricorn,* about 11° west and 3° south of *Jupiter,* and at the end of August the distance has diminished to about 6° west and 2° south. This is on account of the greater westward motion of *Jupiter, Uranus* moving about 2° westward in the period. No bright star is near.

Neptune is in conjunction with the Sun on July 21st, changing from an evening to a morning star, but is too near the Sun for observation even with a telescope.

PLANETARY PHENOMENA FOR SEPTEMBER AND OCTOBER, 1914.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon	Sept. 4,	$6^h\ 1^m$ A.M.	Full Moon	Oct. 3,	$9^h\ 59^m$ P.M.
Last Quarter	" 12,	9 48 A.M.	Last Quarter	" 12,	1 33 A.M.
New Moon	" 19,	1 33 P.M.	New Moon	" 18,	10 33 P.M.
First Quarter	" 26,	4 3 A.M.	First Quarter	" 25,	2 44 P.M.

The fourth and last eclipse of the year, a partial eclipse of the Moon, will occur on the morning of September 4th. No part of it will be visible from the eastern part of the United States, but a part may be seen in the far west. The circumstances of the eclipse are as follows, Pacific time:—

Moon enters penumbra	September 4,	$3^h\ 1^m$ A.M.
Moon enters shadow	" 4,	4 16 A.M.
Middle of eclipse	" 4,	5 55 A.M.
Moon leaves shadow	" 4,	7 33 A.M.
Moon leaves penumbra	" 4,	8 48 A.M.

The maximum obscuration will be 86 per cent of the Moon's diameter.

The autumnal equinox, when the Sun crosses the equator from north to south, occurs September 23d, shortly after 1 P. M. Pacific time.

Mercury on September 1st is an evening star, having passed superior conjunction with the Sun on August 30th, but is entirely too near the Sun for naked-eye view, and this condition remains thruout the month. The planet, however, will become visible as an evening star toward the middle of October. It reaches greatest east elongation, 24° 52′, on October 15th, and then sets not quite an hour and a half after sunset. The greatest elongation is greater than the average, as the planet passed its aphelion on September 29th. The visibility lasts for only a few evenings, as by the end of October the planet has nearly reached inferior conjunction. East elongations during the autumn seldom yield as good conditions for visibility as the present one. There will be two conjunctions of *Mercury* and *Mars*, one on the night of October 5th-6th and the other early in the morning of October 30th. In each case *Mercury* will be a little more than 2° south of *Mars*.

Venus thruout September sets about an hour and three quarters after sunset. The interval shortens about half an hour during October, being about an hour and a quarter on October 31st. It reaches its greatest east elongation from the Sun on the morning of September 18th. The distance, 46° 27′, is perhaps 1° greater than the average, as *Venus* was in aphelion only thirty-six hours before. The almost perfect circularity of her orbit makes all greatest elongations practically of the same size, in strong contradistinction to the case of *Mercury*, where they differ as much as 10°. As seen in the telescope at time of greatest elongation *Venus* will have a half-moon shape. As the planet approaches inferior conjunction the half-moon shape changes to a gradually narrowing crescent, which disappears entirely at conjunction. At the same time the planet is rapidly approaching the Earth and its apparent size is increasing. The brightness of the planet will increase until the planet is about half-way between greatest elongation and inferior conjunction. This occurs on the morning of October

23d. For some weeks before and after this time *Venus* will be bright enuf to be seen in full daylight. It is not always easy to find it by daylight, but when once seen it is very obvious.

Mars is still to be seen in the evening sky, but is so much fainter and so near the Sun that it is not very obvious. On September 1st it sets about an hour and twenty minutes after sunset. This diminishes to less than an hour by October 1st, and to about forty minutes on October 31st. As the planet also almost reaches its greatest distance from the Earth and is at the same time gradually nearing the Sun, it attains its least brightness in October several weeks before time of conjunction with the Sun. Its brightness will vary very little from September 1st to the end of the year, and will be not greatly different from that of a standard second-magnitude star like the Pole Star. The conjunctions of *Mars* and *Mercury* have already been mentioned.

Jupiter is in fine position for evening observation, remaining above the horizon on September 1st until about half-after three, and about half-after eleven on October 31st. It remains in the constellation *Capricorn*, retrogrades or moves westward a little more than 2° until October 9th, and then moves about 1° eastward by the end of the month. It will be in close conjunction with the Moon on the night of September 1st-2d, the morning of September 29th, and at about noon on October 26th. In all three instances the planet is north of the Moon. The last conjunction of the three is the closest, and will be an occultation for some parts of the southern hemisphere.

Saturn rises at about midnight on September 1st and shortly after 8 P. M. on October 31st, so it is getting around again in fair position for evening observation. It is on the border-line of the constellations *Taurus* and *Gemini* and moves eastward nearly 2° until October 15th; it then begins to retrograde and at the end of October is almost exactly in the same position it occupied at the beginning of the month. It is seldom that the line of retrograde motion corresponds so exactly with the line of direct or eastward. The apparent width of the rings remains practically unchanged.

Uranus is also in good position for evening observation, not setting until nearly 3 A. M. on September 1st and not until nearly 11 P. M. on October 31st. Like *Jupiter*, it is in the constellation *Capricorn* and lies 5° to 6° west of the brighter planet. Its motion is small, about 1° westward until October 18th, and then a little eastward. There is no even moderately bright star near enuf to afford an easy identification of the planet.

Neptune rises somewhat after 2 A. M. on September 1st, and shortly before half-past ten on October 31st. It moves about 1° eastward in the extreme western part of *Cancer*.

NOTE ON THE ILLUSTRATIONS IN THIS NUMBER.

The frontispiece of the present number of these *Publications* is a reproduction of a photograph taken by Mr. C. A. BERGMANN, Assistant in the Lick Observatory. The first and third of the frame buildings (counting from the right) and the three-story reinforced concrete building in the center, on the main peak, are the new residence buildings, completed in 1913, to replace the large brick dormitory which had to be taken down on account of damages wrought by the earthquake of July, 1911. The buildings faintly seen in the background on the right are in the city of San Jose, thirteen miles, in a direct line, from the observatory.

The two fog views are also from photographs by Mr. BERGMANN and illustrate typical conditions at Mount Hamilton in the early spring months.

COMMITTEE ON PUBLICATION.

NOTICE TO MEMBERS AND CORRESPONDENTS OF THE SOCIETY.

A General Index of the first twenty-five volumes of these *Publications* will be printed during the present summer and a copy will be sent to each member and correspondent of the Society in lieu of the usual August number of the *Publications*. The price for additional copies, and for copies to those who are not members will be $1.75, postage paid. Orders may be sent to Mr. D. S. RICHARDSON, 752 Phelan Building, San Francisco.

The next regular number of the *Publications* will appear in October, 1914.

COMMITTEE ON PUBLICATION.

NOTES FROM PACIFIC COAST OBSERVATORIES.

THE ZEEMAN AND STARK EFFECTS.

The important discovery by STARK of the effect of an electric field on radiation is of the greatest interest to the physicist, and may prove of equal value to the astronomer. Altho the observed phenomena are in some respects closely analogous to those of the Zeeman effect, there are significant points of distinction which make it possible to determine with certainty whether an electric or a magnetic field is the producing cause. The most important criterion, in cases where the magnetic or electric fields are too weak to produce complete separation, is afforded by the fact that whereas in the Zeeman effect the outer components of a magnetic triplet are circularly polarized when observed in the direction of the lines of force, the components of an electrically resolved line are unpolarized under similar conditions of observation. Thus, disregarding other points of difference, the presence of circularly or elliptically polarized light, if not of instrumental origin, will serve as a sufficient criterion.

In sun-spot triplets, for example, the two outer components are circularly or elliptically polarized in opposite directions, the polarization being so pronounced that either component can be cut off at will in the case of spots lying near the center of the Sun. Furthermore, a wide variety of tests give all of the other peculiarities which the Zeeman effect would lead us to expect. The general magnetic field of the Sun is too weak to resolve the lines into their separate components, but the displacements which have led to its detection result from the fact that the overlapping components are elliptically polarized. Thus, in both cases, there can be no doubt that the observed phenomena are due to a magnetic rather than an electric field.

[illegible]

As for the possibility of detecting the existence of electric fields in the Sun by means of the Stark effect, the existing evidence appears to be negative. In view of the powerful magnetic fields in sun-spots, it seems probable that electric fields of considerable intensity may also be found there. I have examined our photographs of spot spectra with the object of detecting any anomalies ascribable to the Stark effect, but so far without success. Comparatively few of these photographs, however, were taken for the study of plane polarization effects, and in these cases the spots observed were at some distance from the center of the Sun. It will be necessary to repeat the observations with special polarization apparatus in the case of sun-spots lying near the Sun's center and elsewhere, and also to extend them to the chromosphere, with special reference to its lower levels. At present it can only be said that if the Stark effect exists in the Sun its magnitude appears to be so small that special methods, similar to those employed in the study of the general magnetic field, will be required to detect it. Polarizing apparatus suitable for this purpose is described in a paper read before the American Philosophical Society on April 24th.[1] GEORGE E. HALE.

PRELIMINARY NOTE ON THE DISSYMMETRY OF LINES IN THE SPECTRUM OF THE CONDENSED SPARK.

That the strongly condensed spark gives spectrum lines which in general are stronger on the red side is well known. It is difficult to make accurate micrometer settings on such lines, so that spark spectra to be measured are usually obtained with considerable inductance in the circuit, which sharpens the lines and at the same time reduces the tendency toward dissymmetry. As the effect is not easily measured by our usual methods and can be minimized when desired, it has not taken its place as an active agency in the displacing of lines. When a displacement is observed, the probable influences of pressure and of motion in the line of sight are first considered. The condition is to be faced, however, that a source giving strong enhanced lines must bear a certain resemblance to the vapor in the interior of the condensed spark and that a similar displacing influence is to be expected.

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[1] Soon after the appearance in *Nature* of the first announcement of his discovery, I wrote to Professor STARK regarding the determination of the effect for the lines of iron, chromium and other metals found at low levels in sun spots and the solar atmosphere, where intense electric fields may exist. He replied that the absence of series lines in their spectra had led him to omit them from his preliminary program but that he would endeavor to observe the effect for these elements during the coming summer.

Recent tests of the registering micro-photometer, designed by Professor KOCH, which were reported in part in the *Astrophysical Journal*, **39,** 213, 1914, showed that the position of maximum density could be determined, even for lines of very diffuse appearance, by means of the intensity curves which this instrument registers. In order to study the qualitative aspect of the effect and determine the proper conditions for the taking of photographs to be used in the micro-photometer. I have made a number of plates for selected regions of the iron and titanium spark spectra, using a powerful transformer discharge with large capacity and only the small inductance given by the leads. Arc spectra on the same plates showed the structure of the lines in this source. The scale of the plates was about $1^{mm} = 0.9$Å.

The effect of such a spark on those lines which are strong and easily reversed in the arc is very decided. While in the arc these lines are symmetrical, in the spark the red side is usually much stronger. If reversed, the spark gives the reversal much to the violet of the center of the line. Furthermore, this reversal coincides with the position of the arc line, as was shown by photographing the arc spectrum adjacent to that of the spark. Some lines in the blue and violet are given by the spark with the red side fully twice as strong as the violet side, while in the arc the two sides of the reversal are of equal length. That this condition is caused by the interior of the spark giving a line displaced toward the red is well shown when a horizontal cross-section of the spark is projected on the slit of the plane-grating spectrograph. The long line thus produced is strongly unsymmetrical in the middle of its length, where the chief radiation is from the center of the spark, but changes gradually into symmetry toward the ends, showing that the outer vapors of the spark give a line of the same wavelength as the arc.

Iron lines, when of the same character, show this dissymmetry much more uniformly than do those of titanium. The latter element shows most of its stronger arc lines decidedly unsymmetrical in the spark, but some of them remain nearly symmetrical. In addition to these exceptional cases, two important groups of lines show little response to the displacing action of the spark discharge. They are the enhanced lines and the "flame" lines, the latter being strong at low temperature in the electric furnace. These two classes form the extremes of the excitation scale, the "flame" lines being emitted by the outer vapors of the spark and the enhanced lines almost solely by the core. Lines belonging to different groups in the furnace classification show varying degrees of dissymmetry in the spark.

In regard to the important question as to how this effect varies with the wave-length, the preliminary examination shows that the majority of the lines strongly affected lie toward the violet end of the spectrum. This may be closely connected, however, with the fact that the effects of widening and reversal in the arc and spark are more decided in the region of shorter wave-length. The character of the iron spectrum is such that the lines showing the strongest dissymmetry in the spark occur to the violet of λ 4400. With titanium, a strong group near λ 5000 shows the same variety of effects that appear among the blue and violet lines. In all regions the approximate symmetry of the "flame" and enhanced lines is in strong contrast with the appearance of many of the arc lines.

The evidence at present is against a close relation between the effect of the spark discharge and the pressure effect: first, because the spark dissymmetry shows no tendency to increase with the wave-length, but rather the reverse; second, lines of the same pressure displacement are often very different in their spark dissymmetry; third, the enhanced lines, usually strongly affected by pressure, show a minimum spark effect. The fact that some of the "flame" lines are but slightly displaced by pressure and remain symmetrical in the spark is the only point of resemblance between the two effects thus far noted.

The dissymmetries recently described by the writer for the lines of iron and titanium in the "tube-arc," which furnishes spark conditions *in vacuo* without the use of a high potential, correspond in all details, as far as the same regions of the spectrum have been examined, with those produced by the condensed spark. The varying dissymmetries of certain titanium arc lines and the symmetry of the enhanced lines were features noted in the "tube-arc" spectrum. The violently disruptive action of the spark discharge thus does not appear to be essential to the phenomenon.

The evidence at hand points to a real displacing action, highly selective in character, being exerted by the conditions in the interior of the spark. A fairly definite program may be offered for the study of this effect and its application to any spectrum in which the strength of enhanced lines indicate that displacements due to this cause may have a magnitude worth considering. The relative intensity of enhanced and arc lines in the spark spectrum may be controlled within a wide range by adjusting the circuit conditions. The function of the microphotometer will be two-fold: first, to measure the relative strength of the enhanced and arc lines for a given condition by means of the areas of their intensity curves, lines of these two classes being often very different in appearance; and, second, to show for a given line in the spark spectrum where its maximum is located with reference to the position of the corresponding line in the arc, the latter being obtained either from an adjacent arc spectrum, or, in the case of reversed spark lines, from the position of the reversal. The tests already carried out with the micro-photometer brought from Munich by Professor KOCH have shown these measurements to be well within the capabilities of the instrument. A large apparatus of the same type is now under construction here for the work on the large-scale spectrograms. ARTHUR S. KING.

MOUNT WILSON SOLAR OBSERVATORY,
May 14, 1914.

BLINKSTERNE.

For several years Dr. HARTWIG, in the annual *Katalog und Ephemeriden veränderlicher Sterne*, has used the term "antalgol" to designate a small group of variable stars whose light curves are similar to those of the *Algol* variables when rotated thru 180° about the horizontal line, or turned upside down. Dr. HARTWIG has now given up the use of this term and in the catalog and ephemeris for 1914 proposes a new term, "Blinksterne," to be applied to both the antalgol and the δ *Cephei* types of stars. The antalgol stars were formerly put by themselves in Part IV of the catalog, but this has been changed and they are put in Part II, which now includes all short-period variables except those of the *Algol* and β *Lyræ* types.

It seems rather doubtful if a satisfactory translation of the word Blinkstern into English can be obtained. Neither blink-star nor flash-star seems acceptable. Nearly all are agreed, I think, that there is no real difference between δ *Cephei* and antalgol variables, and that they should be put together into one class. The problem is to find a suitable name. If the name suggested is acceptable, it may be best not to attempt a translation into other languages. Dr. HARTWIG'S remarks on this matter are worth quoting in full and I give below a rather free translation, too free to warrant the use of quotation marks.[1]

As for the inclusion of the antalgol stars [in Part II], it appears evident, from more careful investigations of their light changes, that, in the case of most of them, though not all, there is, in reality, no long period of constant light interrupted by a brightening, in contrast to *Algol* stars whose period of constant light is interrupted by an absolutely regularly recurring eclipse; but that, on the contrary, their variability is continuous, and after a gradual declining to a definite minimum there occurs, with extraordinary regularity, a rapid brightening to a maximum of short duration.

The behavior of these stars suggests the appearance of the flash-light in a light-house on the seacoast, which after exactly equal intervals blazes out, and after a short duration, slowly disappears: and I suggest for these stars, which have their oldest representative in δ *Cephei*, the name "Blinksterne." The necessity for a name is in the highest degree weighty and pressing. It is necessary to distinguish these stars from other variables by a characteristic name, and it is to be hoped that the false and misleading term, Cepheids, will soon be given up. Cepheids are meteors which come from the constellation *Cepheus*, as the Perseids are meteors which have their radiant point in the constellation of *Perseus*. If one should call the Algol stars Perseids, after the oldest representative, *β Persei*, then everyone would immediately recognize the incorrectness of the designation. The name Cepheid is, in quite the same way, incorrect and misleading. The name Cluster Star, taken up in America, is also not suitable, because this kind of a variation is not a general property of the stars in clusters, and not even of all the variables in clusters, and not all the stars having this kind of variation are located in clusters. For the present it is not possible to establish with certainty a class distinction expressed in length of period, even tho there seem to be short-period groups and long-period groups. Therefore these stars, with their great regularity, their sudden, rapid rise to maximum and their slow decrease, can be placed together under the common name of "Blinksterne." If the stars U *Geminorum*, SS *Cygni* and SS *Auriga* were regular in the times of their brightening, then they would be true examples of antalgol stars, because their increase of light comes after long periods of constant light. S. D. TOWNLEY.

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[1] *Vierteljahrsschrift der Astronomischen Gesellschaft*, 48, 287.

STANFORD UNIVERSITY, CAL.

SOME ELECTRIC FURNACE EXPERIMENTS ON THE EMISSION OF ENHANCED LINES IN HYDROGEN ATMOSPHERE.[1]

A very interesting paper with the above title by **ARTHUR S. KING** is soon to appear in the *Contributions from the Mount Wilson Solar Observatory*. Dr. **KING** has kindly furnished a manuscript copy to be abstracted for this issue of the *Publications*.

The experiments discussed in this paper were undertaken to test the hypothesis that the presence of hydrogen may facilitate the emission by metallic vapors of the so-called enhanced lines. This hypothesis was first suggested by the fact that the arc in a hydrogen atmosphere shows the enhanced lines stronger than in air. It is also known, however, that, for the same distance between terminals, the arc is maintained with greater difficulty in an atmosphere of hydrogen than in air and that the discharge is characterized by a higher potential gradient. indicating an approach to the conditions of the spark discharge.

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[1] Abstract by E. S. HAYNES.

The question is thus raised whether the action of hydrogen in producing from the arc those lines which are intensified in the spectrum of the spark is not simply to alter the conditions of the arc discharge toward those of the spark.

The electric furnace seems especially adapted to test this question, because the graphite tube of the furnace may be expected to perform its functions as an exciting source independently, to a large extent, of the surrounding gas, leaving the conditions of mixed vapors, density and total pressure to produce any effects that may be observed.

Dr. King gives the following summary of the results of his work with the electric furnace:—

1. The experiments "have failed to show any effect of a hydrogen atmosphere in strengthening enhanced lines. They appear in the furnace at low pressure with equal ease whether hydrogen is present or the furnace contains a residue of air.

2. "Widely different amounts of titanium vapor at low pressure and the same temperature have shown no material effect on the relative intensities of enhanced lines.

3. "Increasing the pressure of hydrogen, the temperature being held as nearly constant as possible, causes a progressive weakening of the titanium enhanced lines, until at atmospheric pressure only traces of the strongest are visible in the furnace spectrum."

It is thus seen that neither the presence of hydrogen nor the density of the radiating vapor materially affects the strength of the enhanced lines, but that the total pressure is very important in this respect. Previous experiments have shown that the arc lines are not thus affected by the pressure; but experiments with the furnace, the tube arc and the ordinary arc at low pressures have shown that the enhanced lines are brought out best in a partial vacuum, a condition favorable to all the phenomena of electro-luminescence.

Since the occurrence of enhanced lines in stellar spectra is usually accompanied by strong hydrogen emission, it has been suggested that the enhancement is due in some unknown manner to the presence of the hydrogen. The present experiments render this view improbable. The probable manner of the production of enhanced lines in stellar atmospheres appears much clearer since the discharge of electrons from hot bodies has been investigated for the relatively low temperatures of the electric furnace, this action having been shown to persist at very high pressures. The high stellar temperatures, especially when combined with low pressure, may thus be expected to duplicate the electronic speeds obtained in the arc and spark by steep potential gradients, a condition established by much evidence as favorable to the enhanced lines.

The enhanced lines in the chromosphere would thus seem to be due to the rarefied conditions at these levels of the solar atmosphere, which would allow a high speed to be retained by the electrons expelled by the heated matter below. The strength of the enhanced lines would also seem to be a valuable criterion as to the temperatures prevailing in stars and in different regions of the solar photosphere at levels where the electrified particles are produced. Thus the reduced strength of enhanced lines in sun-spot spectra seems valid evidence of a lower temperature for the photosphere of those regions, since such a reduced temperature, the pressure being assumed essentially the same, would result in the production of lower-speed electrons.

VOLUME VII, PUBLICATIONS OF THE LICK OBSERVATORY.

This volume, whose title is "Contributions of the Berkeley Astronomical Department (Students' Observatory), University of California, I," is now being distributed to the correspondents of the Lick Observatory. It comprises ten parts, seven of which are devoted to the exposition of LEUSCHNER's Short Methods of Determining Orbits, and to practical applications of these methods to the computation of the orbits of comets, asteroids and satellites. The theoretical papers are by Professor A. O. LEUSCHNER, while the chapters giving the practical applications are by Professor R. T. CRAWFORD, and by assistants and students in the Students' Observatory.

The volume also contains a paper "On Astronomical Refraction" by Professor CRAWFORD, and two papers by Dr. B. L. NEWKIRK entitled, respectively, "Tables for the Reduction of Photographic Measures" and "Investigation of the Repsold Measuring Apparatus."

Parts I, II and III of the volume were printed in 1902; the following parts were prepared and partly printed in subsequent years from 1905 to 1911, but lack of University funds at the State Printing Office prevented the completion of the volume until the present time.

NOTE ON COMET *a* 1914 (KRITZINGER).

The first comet of this year was discovered by **KRITZINGER** at Bothkamp, Germany, on March 28th. From observations of March 29th by **KRITZINGER**, of March 30th by **PALISA** in Vienna, and of April 1st by **HAYNES** at the Lick Observatory, Miss **SOPHIA H. LEVY** and I derived the orbit of the comet.

Our results show that it is moving in a plane inclined 23° 36′ to the plane of the ecliptic. At the time of discovery the comet was approaching both the Sun and the Earth. It makes its nearest approach to the Sun on the 31st of May at a distance of 116.6 million miles. Its closest approach to the Earth will also be in the latter part of May. It will come within less than fifty million miles of the Earth. The comet will continue to increase in brightness until the end of May or first part of June, when it will begin to fade away rapidly.

The elements of the orbit, together with an ephemeris extending to April 19th, were published in *Lick Observatory Bulletin*, No. 253. R. T. **CRAWFORD**.

BERKELEY ASTRONOMICAL DEPARTMENT,
May 16, 1914.

A NEW COMET.

Telegrams received at the Lick Observatory on Monday, May 18th, announced the discovery of a comet by M. **ZELATINSKY**, an amateur astronomer in Russia, and gave observations of it made on the nights of May 16th and May 17th by M. **SCHORR** and M. **VAN DER BILT**, respectively.

As seen with the 12-inch refractor on the evening of May 18th, the comet appeared to be of about the seventh magnitude, with a sharply marked disk-like nucleus placed somewhat north of and preceding the center of the coma. No definite evidence of a tail was presented. The very rapid motion indicated that the comet was near the Earth, and this has been confirmed by its rapid increase in brightness. On Thursday night, May 21st, it was readily visible to the unaided eye, and the telescope showed a tail fully 2° long.

From the observations of May 16th, 17th and 18th, CRAWFORD and Miss LEVY have computed the following preliminary elements, which show that the comet has already passed its nearest point of approach to the Sun and is now as near the Earth as it will come. Its brightness will probably diminish rather rapidly.

ELEMENTS.

$T =$ May 8.38, 1914, G. M. T.
$\omega = 116° \ 22'$
$\Omega = \ 32 \ \ 36$
$i = 112 \ \ 59$
$q = 0.543$

R. G. AITKEN.

May 22, 1914.

PERSONALS.

Dr. ELI STUART HAYNES, Martin Kellogg Fellow in the Lick Observatory, University of California, during the current academic year, has been appointed Associate Professor of Astronomy in Beloit College, Beloit, Wisconsin.

CHARLES EDWARD ADAMS, M. Sc., F. R. A. S., Government Astronomer of New Zealand, the Hector Observatory, Wellington, has been appointed Martin Kellogg Fellow in the Lick Observatory for the academic year 1914-1915.

WARREN KIMBALL GREEN, A. B., Harvard University, 1913, has been appointed Fellow in the Lick Observatory for the academic year beginning July 1, 1914.

SETH B. NICHOLSON, Instructor in Astronomy in the Berkeley Astronomical Department, University of California, is spending the summer vacation in the Lick Observatory as a volunteer observer.

Dr. W. W. COBLENTZ, member of the staff of the Bureau of Standards, Washington, D. C., will be a Special Investigator in the Lick Observatory during several months this summer, for the purpose of studying stellar radiations with the help of special electrical apparatus attached to the Crossley reflector.

Dr. S. D. TOWNLEY, of Stanford University, will be a Special Investigator in the Lick Observatory during several months this year. His attention will be devoted to a study of certain interesting variable stars.

Senior Astronomer RICHARD HAWLEY TUCKER, of the Lick Observatory staff, and Miss RUTH STANDEN, of Toronto, Canada, were married on April 29th, at Trinity Church, San José, California.

Director CAMPBELL and Astronomer H. D. CURTIS left Mount Hamilton early in June for Russia, where they will establish the observing station of the Crocker Eclipse Expedition in the vicinity of the city of Kiev. They expect to be at the observing station from July 21st to August 26th, and their mail address during this interval will be in care of St. Petersburger Internationale Handelsbank, Kiev, Russia. Director CAMPBELL's family accompanies him, and there will be a number of volunteer observers in the party. After the work of the expedition has closed Messrs. CAMPBELL and CURTIS will attend the meeting of the Astronomische Gesellschaft in St. Petersburg and Pulkowa. They plan to return to Mount Hamilton about October 10th.

ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these *Publications*, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

THE DENSE FLINT AND LIGHT FLINT PRISM.

The search for the most efficient dispersing element for the low-dispersion spectrograph of the Dominion Observatory has led Dr. PLASKETT to try different kinds of glass, as well as a grating. His report in the November-December, 1913, number of the *Journal of the Royal Astronomical Society of Canada* contains the following points: The dense flint glass *O 102* most frequently used for stellar spectrographs is somewhat yellow and strongly absorbing of violet light beyond λ 4000.

In many early-type star spectra the *K* line of calcium is the best for measurement of velocity; and in many other early-type stars in which only hydrogen lines are present greater accuracy would be gained if a greater number of hydrogen lines were available on the spectrograms. With the dense flint prism the *K* line can be obtained only by over-exposing the region between $H\beta$ and $H\gamma$ and losing narrow lines. Some months ago experiments with a plane grating[1] showed that, altho only 30 per cent of the light was diffracted into the first order spectrum, the spectrum was more uniform in intensity and stronger to the violet, but not much improved at the *K* line. Consequently it was not greatly advantageous to use the grating instead of the prism. Experiments by WILSING had shown the light flint transmitted more than twice as much *K* light as the dense flint. It was therefore inferred that the baryta light flint *O 722* might offer the improvement sought. A prism of baryta light flint *O 722* glass was ordered with refracting angle of 69°. When received it was mounted with

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[1] *Publ. A. S. P.*, **25**, 306, Dec. 1913.

λ 4200 central. It gives star spectra very uniform in intensity from $H\beta$ to much beyond K in remarkably less exposure time. The dispersion is 55 ångstroms to the millimeter, which is three fifths of the dispersion of the dense flint prism; but it could be made the same by using a camera of greater focal length. For equal dispersions the relative exposures of the light flint to the dense flint prism are found to be, for $H\beta$ λ 4861, 60 per cent, and for K λ 3933, 26 per cent. An exposure on early-type stars of half that with the dense flint prism secures six hydrogen lines beyond $H\epsilon$ of sufficient intensity to be measured, whereas $H\zeta$, the first of the six, is not measurable on spectrograms taken with the dense flint prism.

The smaller dispersion and longer camera would theoretically diminish the resolving power and definition of the spectrograph, but this would have practically no effect on most early-type spectra the lines of which are generally wide, broad, or diffuse. It is obvious, therefore, that the light flint prism has much advantage over the dense flint prism, both by increasing the extent of uniform intensity and the number of measurable lines and by diminishing the exposure time.

G. F. PADDOCK.

March, 1914.

THE WAVE-LENGTH OF X-RAYS AND ANALYSIS OF CRYSTALS.

It was recently found by LAUE that X-Rays or the heterogeneous radiation from the anti-cathode of a vacuum bulb, could be reflected by crystals and photographs made of the reflected radiation. The photographs showed a central spot surrounded by numerous smaller and fainter spots in various geometrical arrangements, depending upon the kind of crystal. The figures have been called LAUE's diffraction patterns. Subsequently W. H. BRAGG[1] of Leeds and W. L. BRAGG of Cambridge devised the X-Ray spectrometer, similar to a light spectrometer. The crystal is mounted on a rotating table. A lead block acting as a diaphram takes the place of a collimator. An ionization chamber takes the place of a telescope or camera. With this instrument, they used homogeneous radiation from anti-cathodes of platinum, palladium and rhodium. They found that the reflected radiation, whose intensity is indicated by amount of ionization, is of two forms—continuous and selective. The latter consists of groups of points of increased intensity corresponding to particular angles of reflection. These points or peaks in the intensity curves are found to satisfy the formula—

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[1] *Proc. Roy. Soc. London*, 88, 89, 1913, 1914.

$$n\lambda = 2d \sin \theta,$$

in which θ is the angle of reflection determined by the relative position of crystal and ionization chamber; d the distance between the successive planes in which molecules or atoms are arranged in a crystal, determined by means of the atomic weight and density of the crystal; λ the wave-length; n a whole number pertaining to the particular group of intensity peaks and corresponding to successive orders of diffraction spectra.

By means of this formula the wave-length λ may be determined. The form of the intensity curve and the value of λ are found to vary with the nature of the anti-cathode and to be typical of the substance. Each metal seems to have an X-Ray spectrum just as each has a light emission spectrum. The principal wave-lengths measured in tenth-meters or ångstroms, which are one-ten-billionth part of a meter, have been found for a few metals. For example:—

Platinum,	1.10×10^{-10} ångstroms,	with rock-salt crystal.
Palladium,	0.576×10^{-10} ångstroms,	with diamond crystal.
Rhodium,	0.607×10^{-10} ångstroms,	with diamond crystal.

The X-Ray wave-length is then of the same order as the unit of light wave-length measurement—one ångstrom. Since the distance between atoms is of the order of 100 ångstroms, so that the size of atoms is less than 100 ångstroms, it is probable that their size is more or less the same as the infinitessimal magnitude of the X-Ray wave-length. This would be the case if the observed reflection of X-Rays is produced by their diffraction by the lines of atoms formed by crystalization. In fact, Professor BRAGG has concluded that the elements of crystalline structure have geometrical forms such as cubes and rhombohedrons, etc., with the atoms at their corners, in their centers, in the center of their faces, etc. The atoms thus form in effect parallel lines in parallel planes, which act in a manner similar to the lines in the plane grating. In fact, the reflection of the X-Rays evidently takes place within the crystal and not on the crystal faces.

Professor BRAGG has arrived at these conclusions as a result of the crystal analysis made possible by the X-Rays and the spectrometer. For example, taking the crystal of rock-salt, whose molecules are composed of equal numbers of atoms of sodium and of chlorine, the analysis leads to the idea of a cube with four atoms of sodium at four corners, which are in diagonal relation to one another, and four atoms of chlorine at the other four corners which are in diagonal relation to one another. Obviously, planes formed by the opposite faces contain the same kind and numbers and arrangement of atoms; but planes cutting the cubes and their faces diagonally contain alternately only sodium and only chlorine atoms. It is found from various kinds of crystals that these different systems of planes give spectra either all alike or alternately alike, or repeating groups of varying spectra. For instance, different atoms of different atomic weight or different arrangements give different forms and different intensities in their spectrà. If then a sufficient number of planes of different orientations be examined so as to give the exact spacing and relative masses of the planes or atoms, a solution of the geometrical arrangements may be obtained. Thus the atomic structure of any crystal, however complicated, may be investigated and delineated. It is found that the molecular element of the diamond is a cube with atoms of carbon at every corner and in the center of each face; that of sulphur is an oblong or orthorhombohedron with atoms of sulphur at every corner and in the centers of the end faces only; that of quartz is a hexagonal parallelopipidon with atoms at each of the twelve corners and in the centers of the hexagonal faces; that of calcite or calcium carbonate is a rhombohedron with atoms of calcium at every corner and in the center of every face; atoms of carbon at the middle point of every edge, and atoms of oxygen on certain lines joining certain carbon atoms. The latter is an example of the complexity that crystals may possess.

March, 1914. G. F. PADDOCK.

GENERAL NOTES.

Reinforced Concrete and Steel Dome Struck by Lightning.—To astronomers especially and to all those interested in reinforced concrete construction, where lightning is prevalent, its effect on such structures is of interest.

On the afternoon of January 2d the just-completed (but unpainted) dome for the astrographic telescope was struck by lightning during a very heavy thunder-storm. A workman in the yard of the Oficina Meteorológica, about 100 meters distant, was facing the dome and saw the bolt strike. He described it as "descending to the lightning-rod in a single ray, but immediately after the entire dome was covered with sparks."

One of our workmen was in the dome at the time cleaning the running gear, but felt nothing. Nor can any signs of sparks or damage be found.

The fuses on the power circuit, which passes close to the dome, were blown by this flash. The light circuit was cut several times during the heaviest of the storm, all probably by induced currents.

The walls of the dome are strongly reinforced with I-beams and twisted iron rods. The grounding of the lightning-rod is effected by a short length of three-eighth copper cable, which connects the rail on which the dome rotates to one of the vertical three-inch I-beams in the corners of the walls. The dome is covered with heavy galvanized iron riveted directly to the frame.

The derrick used in construction, the top of which was about two feet higher than the top of the lightning-rod, was still standing. What part it played in carrying the discharge is uncertain. The grounding of the wire guys was not good, however.

The top of the dome is about forty-two feet above the surface of the ground and of the lightning-rod forty-five feet.

C. D. PERRINE.

OBSERVATORIO NACIONAL ARGENTINO,
CÓRDOBA, February 8, 1914.

FOG IN THE VALLEYS AT TWILIGHT.

The Retirement of Professor S. W. Burnham.—It is stated in *Science* that Professor S. W. Burnham, of the staff of the Yerkes Observatory, will retire on July 1, 1914. This will close the active work of one of the most remarkable astronomical observers of modern times.

It was in 1861 that Burnham purchased his first astronomical telescope, and, in a sense, it may be said that his observational work began at that time. But the six-inch Clark refractor which he made famous was not ordered until 1869, and the first new double star discovered that is retained in his catalogs (B 40) was found with this telescope on the night of April 27, 1870.

The work Burnham accomplished with this telescope marked a new epoch in the history of double-star astronomy, and put him in the front rank of observers. No less than 451 new double stars, many of them more difficult than any previously found, were discovered with it. His later work with other and larger telescopes was equally successful, and he well deserves the tribute Campbell[1] has paid him in saying: "It was he who first developed the full power of modern telescopes in double-star discovery and measurement." Burnham's work, however, has not been confined entirely to observations of double-stars. He has published numerous papers giving the results of his studies of individual stars and two great general catalogs, one of his own discoveries and one containing a concise but complete history of every double star within 121° of the north pole which had been discovered prior to 1906.

Campbell concludes the sentence quoted above by saying, "and his fruitful researches still continue." It is the earnest hope of every one interested in double-star astronomy that, notwithstanding Burnham's retirement from active observing, we may long be able to say this of him. R. G. A.

Miss Annie J. Cannon of the Harvard College Observatory has been elected an honorary member of the Royal Astronomical Society of London. Miss Cannon is in charge of the great library of astronomical photographs which the observatory possesses and is at present engaged in making a comprehensive catalog of stellar spectra. With reference to this, Professor E. C. PICKERING make the following statement in his address as President of the American Association for the Advancement of Science, at Atlanta, December 29, 1913: "During the last two or three years a great demand has arisen for the class of spectrum of large numbers of stars. The Harvard photographs show the class of spectrum of nearly two hundred thousand stars. Miss CANNON has, accordingly, undertaken to prepare a catalog of these objects, with the result that she has already classified about one hundred and fifteen thousand spectra, covering more than one half of the sky. The work is progressing at the rate of five thousand stars monthly, and the results will fill seven of the large quarto *Annals* of the Harvard Observatory. The organization of this work has required the most careful application of the principles of scientific management."

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[1] "Stellar Motions," p 236.

The William Ellery Hale Lectures of the National Academy of Sciences were inaugurated by Sir ERNEST RUTHERFORD, of the University of Manchester, England, who spoke in the auditorium of the National Museum, Washington, D. C., on April 21 and April 23, 1914, on the general subject of the "Constitution of Matter and the Evolution of the Elements."

It is the design of these lectures, which were founded in memory of the late WILLIAM ELLERY HALE of Chicago, "to give a clear and comprehensive outline of the broad features of inorganic and organic evolution in the light of modern research."

"The second course in the Evolution Series will be given at the next autumn meeting of the Academy by Dr. WILLIAM WALLACE CAMPBELL, Director of the Lick Observatory, Mount Hamilton, California. Provided with his raw material, as it were, by Sir ERNEST RUTHERFORD, Dr. CAMPBELL will sketch the various types of bodies which make up the universe, describe their connection in systems, and explain the principal theories of stellar evolution. His object will be to show how stars and stellar systems are gradually evolved from an earlier state and to afford a view of the Earth in its first phases of development. In this way the intimate relationship of the Earth with the Moon and the other bodies of the solar system will be made apparent, as well as the continuity of the process which connects the present with the remote past. Dr. CAMPBELL will introduce some of the results of his extensive researches with the powerful instruments of the Lick Observatory and will employ a large collection of astronomical photographs for purposes of illustration.

"A distinguished European geologist will be invited to give the third course of lectures at the annual meeting of the Academy in 1915. Taking the Earth from the hands of the astronomer, he will show how its surface features have been altered in the process of time. Later lectures, preserving the continuity of the series, will then enter the field of organic evolution and illustrate the bearing of recent investigations in paleontology, zoology and botany on the evolution of plant and animal life. The evolution of man will form the subject of a subsequent course, and the series will close with an account of the rise of the earlier civilizations, coming into touch with the modern times in the life of the Nile Valley."

Professor FREDERICK SLOCUM has been elected professor of astronomy at Wesleyan University, Middletown, Conn. He will also be the director of the new observatory there that is to be built during the coming year. According to a note in *Popular Astronomy*, this observatory is to be erected from a bequest of $60,000 by JOSEPH VAN VLECK, and is to be a memorial to his brother, Professor J. M. VAN VLECK, who was at the head of the astronomical department at Wesleyan for many years.

Dr. EDWARD A. FATH has resigned his position as professor of astronomy at Beloit College to accept the presidency of Redfield College, South Dakota. His successor at Beloit will be Dr. E. S. HAYNES, who at present holds the Martin Kellogg Fellowship in the Lick Observatory. Dr. HAYNES will enter upon his new duties at the beginning of the autumn semester of this year.

"Professor A. S. EDDINGTON has been elected director of the Cambridge Observatory in succession to the late Sir ROBERT BALL. Readers who are unfamiliar with Cambridge are likely to find the recent reorganization of the astronomical work there somewhat confusing. The university now possesses two observatories, which, however, stand in the same grounds. The one devoted mainly to astronomy of position is called simply 'the observatory,' and it is to this that the above appointment relates. The other is the solar physics observatory, which includes also the astrophysical work; this is under the direction of the professor of astrophysics, Professor H. F. NEWALL."—*The Observatory.*

Attention was called in an earlier number of these *Publications* to the "Monthly Report on *Mars*," which is being published by Professor W. H. PICKERING in *Popular Astronomy*. The fifth report appears in the May number of that periodical and contains a very interesting discussion of the double canals of *Mars.*

Mr. STORRS B. BARRETT has been elected assistant professor at the Yerkes Observatory, and Mr. OLIVER J. LEE instructor in astronomy at the University of Chicago. — *Popular Astronomy.*

Professor S. A. MITCHELL, director of the Lander McCormick Observatory of the University of Virginia, has been appointed Ernest Kempton Adams Research Fellow of Columbia University for 1914-1915.

The Bradley Prize.—It is announced that the money subscribed in connection with the jubilee celebration of Dr. ARTHUR AUWERS has been handed over to the Berlin Academy of Science for the foundation of a Bradley Prize. The prize is to be awarded for the first time in 1918 and at intervals of five years thereafter.

Announcement is made in *Science,* of the death of Dr. GEORGE WILLIAM HILL, the great mathematical astronomer, to whom the Society awarded the Bruce Medal in 1909.

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Mr. R. T. Crawford	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. S. D. Townley	*Second Vice-President*
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Comet Medal Committee Messrs. W. W. Campbell, R. H. Tucker, and H. D. Curtis.

NOTICE

Article VIII of the By Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

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Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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NOTE ON THE RADIATION FROM STARS.

By W. W. COBLENTZ.

The termination of the present investigation marks a new epoch in radiometry, especially as applied to the measurement of weak radiations. It makes available to the astronomer one more instrument for the investigation of celestial objects. This, of course is not the first attempt to measure the radiation ("heat") from stars. The previous ones were the stepping-stones which gave positive indications of heat from stars.

We "see" the stars with our eyes, and it goes without saying that when we can produce instruments which are proportionately sensitive to the eye, we shall be able to measure the "light," the radiations, emitted by stars.

The present instrument (a thermo-element) is perhaps a hundred times as sensitive as some of the radiometers used in previous attempts at the measurement of stellar radiation. With it quantitative measurements were made on stars down to the fifth magnitude and highly qualitative measurements were made on stars down to the seventh magnitude.

At various times during the past three or more years stellar thermopiles were constructed. In the early attempts several thermojunctions were placed in a small space—about 1^{mm} in diameter. As I became more familiar with the astronomical side of the problem and realized that a star image at best is a mere point of light, the mode of construction was entirely reversed. The utmost simplicity of construction was undertaken. Instead of several thermojunctions (a "thermopile") a single thermoelement is now employed. The materials used (bismuth and platinum; or bismuth and an alloy of bismuth and 3 per cent tin) are of the smallest workable dimensions to reduce the heat capacity. In fact, the sensitivity attainable depends more upon low heat capacity and low heat conductivity than upon the thermo-electric power of the material used.

The receivers attached to the thermojunctions were 0.3^{mm} to 0.4^{mm} in diameter. From two to three of these thermo-elements were mounted in a glass receptacle (shown in Figure 1, *E*) and the best element was used in making the measurements. The air was exhausted through the stop-cock, *S*. The last traces of air were absorbed by heating metallic calcium, *Ca*, contained in a quartz-glass tube. The vacuum was tested by joining the terminals, *P*, to an induction coil. The rays from a star, after reflection from the mirror pass through the fluorite window, *F*, and are brought to focus on the receiver, *E*. The rear side of the receptacle is covered with a thick piece of plate glass, *G*, thru which is made the adjustment of the star image upon the thermoelement. The whole is mounted in a metal box (*B*, Figure 2), which is attached to the photographic plate holder of the reflector by means of the two screws, *S*. An absorption cell of water, 1^{cm} in thickness, is contained in the hinged metal box, *A*. The metal box, *L*, containing the right-angled prism and a lens for viewing the star-image from the side of the telescope tube, are the regular attachments to the Crossley reflector. The whole is mounted in the central axis of the reflector, with the glass tube pointing downward toward the large reflecting mirror. These attachments were constructed in Washington, D. C., and carried to Mt. Hamilton, Cal., a distance of over 3,100 miles without serious mishap. A vacuum pump was shipped, but it was not unpacked. The equipment consisted of two glass holders as shown in Figure 1. The slight vapors given off from the cement and stop-cock grease were removed by occasionally heating the calcium by means of a small alcohol blast lamp.

The electric current generated by the thermoelement, when a star image was focused upon one of the receivers, was measured by means of an iron-clad Thomson galvanometer, shown in Figure 3. In the galvanometer the coils are imbedded in blocks of Swedish iron. One of the outer iron shields (of

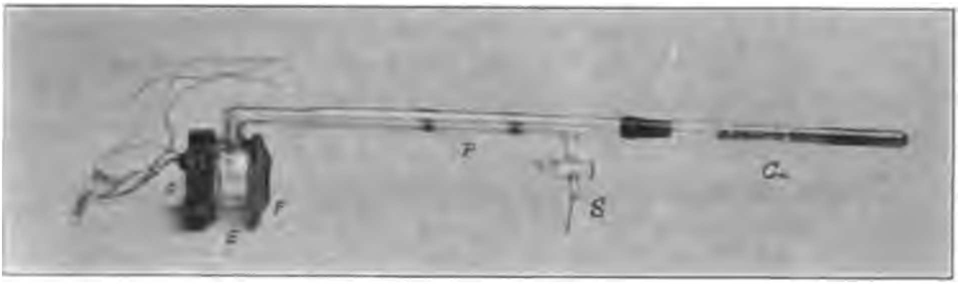


FIGURE I.

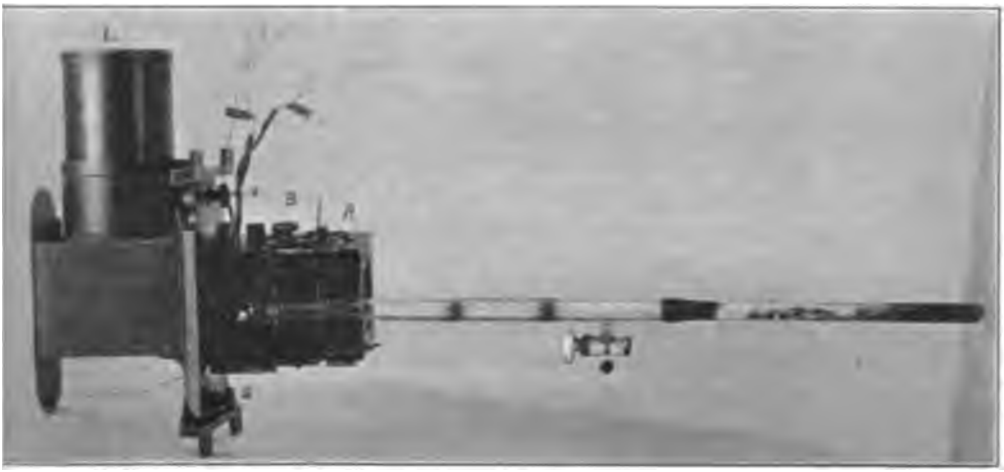


FIGURE 2.

transformer iron) is shown in Figure 3. The galvanometer stood upon the south pier, which supports the reflector. Only when the telescope was pointed low to the northern sky, which brought the lower end of the telescope tube close to (within one meter of) the galvanometer, did the rotation of the telescope affect the galvanometer. A galvanometer reading could be obtained in three to four seconds.

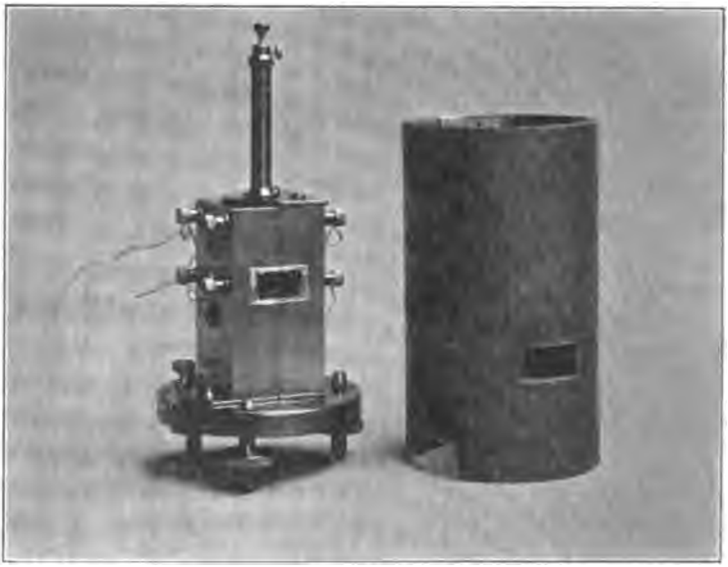


FIGURE 3.

The mirror of the Crossley reflector is 534^{cm} in focal length and it has an aperture of 92^{cm}. The support for the plate holder is 22^{cm} in diameter. In other words, the central position of the mirror, 22^{cm} in diameter, is shadowed by the plate-holder.

The thermoelement differs from the selenium and photoelectric cells, first, in that it is non-selective to the rays of different frequencies falling upon it, i. e. it absorbs all the radiations of all frequencies falling upon it, and, second, in that the response to the stimulus (the heating effect) is proportional to the energy falling upon it. It is an instrument adapted to quantitative measurements of radiant energy. It is far less sensitive than the selenium cell. The latter is, of course, not adapted to solving some of the problems discussed on a subsequent page.

From this brief description, it is evident that one of the principal achievements is in demonstrating that with an equipment of several thermoelements mounted in evacuated receptacles, one can go to the remotest station for radiation measurements without taking a cumbersome vacuum pump.

The whole work being merely a preliminary survey to determine what is possible by way of observing spectral energy curves of stars, no special pier was provided for the galvanometer, and no attempt was made to attain a high galvanometer sensitivity. In fact, the current sensitivity, which was of the order of $i = 2 \times 10^{-10}$ ampere, did not exceed that usually employed at the Bureau of Standards.

RESULTS OF THE RADIATION MEASUREMENTS.

The data obtained on stellar radiation, by means of these instruments, are too extensive to permit a detailed description in this brief note. The radiation from over one hundred celestial objects has been measured. No measurements were attempted on stars of less than the seventh magnitude, owing to the difficulty (lack of illumination) in projecting the star-image centrally upon the receiver. Furthermore, it was not apparent that much would be achieved in this preliminary work by so doing. The humidity during the summer nights on Mt. Hamilton falls below 10 per cent and any slight variations in humidity have a marked effect upon the radiometric measurements, especially upon red stars, which have the property of emitting a great amount of infra-red radiation.

As standards of radiation for intercomparing the observations, made on different nights, *Arcturus, Vega, Altair, γ Draconis*, and other stars were used.

After observing for several nights, it was found that the red stars emitted far more radiation than the blue ones having the same visual magnitude, and attention was given mainly to the solution of this question. Accordingly stars were selected having the same magnitude, but differing in color; and which were close together to eliminate the effect of air mass.

As the work progressed, it became a rather instinctive feeling to avoid the blue stars of less than the fourth magnitude, owing to the difficulty of measuring their radiation. But if this had been merely an attempt to show the possibilities of the instruments, then by selecting red stars, and by increasing the galvanometer sensitivity, positive indications could have been obtained of radiation from stars of the eighth to ninth magnitude. That, however, would simply be a spectacular achievement, and under the present conditions of observation, could not contribute much to science.

The detailed data, which have been accumulated, will be published elsewhere as soon as possible. A general survey of the data at hand indicates, first, that the individual stars of any given spectral class (say Class F), having the same photometric brightness, differ in the amount of energy emitted. This is, of course, to be expected, for no two stars can be expected to have exactly the same emissivity. Furthermore, their size, density and chemical constitution are no doubt vastly different. Second, the stars of different spectral classes (e. g. Class B as compared with Class M) differ greatly in emissivity. The blue stars (Class B, A) radiate much less energy (perhaps 50 per cent less) than the solar stars (Class F, G), and the latter, in turn, emit a less amount of energy than the red stars (Class M). The stars of Class M in general no doubt emit less energy than do the stars of Class N. The star ϕ *Pegasi*, Mag. = 5.23, Class Ma, gave a deflection of 2.8^{mm}, while the much redder star, 19 *Piscium*, Mag. = 5.30, Class N, gave a deflection of 5.7^{mm}. Only one star of Class N was conveniently placed for observation; but from the observations on numerous stars of Class M as compared with blue and yellow stars of the same magnitude, it is to be expected that stars of Class N will be found to have, as a general rule, the highest emissivity of all. Among all the data thus far accumulated, there are no exceptions to this general classification.

In Class M two stars (β *Pegasi* and α *Herculis*) are conspicuous for what may be termed an excessive total radiation, as compared with their photometric brightness. Instead of causing a galvanometer deflection of only a few millimeters they produced a deflection of two to three centimeters.

Of the double stars, measured radiometrically, the star γ *Andromedæ* is an excellent example. The star A (Mag. = 2.28) belongs to the Class K, and the component, BC (Mag. = 5.1) is blue. The intensity of the radiation from the latter is perhaps only about one half that observed from the red star H. R. 7676 *Draconis* (Class Ma), which has a photometric magnitude of 5.4.

To some, of course, the information gained radiometrically is not unexpected. The pioneering work of NICHOLS, some 14 years ago, showed that *Vega* and *Arcturus,* which have closely the same visual magnitude, differ greatly in their total radiation. He found the ratio of their emission (*Arcturus* to *Vega*) to be 2.2. My own observations, for different atmospheric conditions, give a value of 2.42 for the relative intensities of the radiation from *Arcturus* and *Vega.* Of course no conclusions could be drawn from observations on a single pair of stars, and the present generalization, which is based upon the measurement of over five score celestial objects, may also eventually require modification. Thus far, however, no exceptions have been found under the conditions imposed, viz., first, stars close together to eliminate the question of air mass; second, stars of the same visual brightness but differing in color. It was found that the red stars suffer the greatest absorption by water vapor, as was to be expected; but since they are observed to emit the most radiation the conclusions drawn are not invalidated.

The total radiation received from a star is a function of its size, distance, temperature, and especially of its emissivity. The latter is a function of the kind and the physical condition of the material which forms the radiating layer of the stellar surface. To eliminate the effect of the size and the distance of a star upon the quality of the radiations received, measurements were made in which the stellar rays were passed thru a layer of water 1^{cm} in thickness. The water absorbs all the infrared rays of wave-lengths greater than $1.4\ \mu$, and gives a rough comparison of the distribution of energy in the spectrum. The ratio of the galvanometer deflection caused by the stellar rays falling upon the thermoelement after passing thru the water (i. e. those rays which are transmitted by the cell of water) to the deflection caused by all the stellar rays collected by the mirror and concentrated upon the thermoelement, gives the "*transmission*." If the total radiation from a red star contains more infra-red rays than does the total radiation from a blue star, then the amount transmitted by the water cell will be less for the red than for the blue star. This is the true condition of affairs, as may be noticed in Table I, which gives the percentage of the total energy falling upon the thermopile, which is transmitted by the water-cell, for red, yellow, and blue stars.

TABLE I.

	Transmission thru water-cell.
Class B, A—	
α *Lyræ*, A	58%
α *Aquila*, A_5	69
Class F, G, K—	
α *Auriga*, G	48
α *Bootis*, K	45
α *Tauri*, K_5	35
γ *Draconis*, K_5	32
Class M—	
β *Pegasi*, Mb	29
α *Scorpii*, Map	27
α *Herculis*, Mb	21

From this table it may be seen that as much as 60 per cent of all the radiations coming from a blue star, lies in the spectral region to which the eye is sensitive, while only from 20 to 30 per cent of the total radiation received from a red star affects the eye and the photographic plate. This brings out very clearly why it is that a red star of the same visual magnitude as a blue star (causes a larger galvanometer deflection) emits from two to three times as much total radiation. It means that from 70 to 80 per cent of the radiation from a red star lies in the infra-red—beyond the spectral region to which the eye is sensitive.

The absorption cell tells us nothing of the size and the distance of the star. It simply indicates that the shape of the stellar spectral energy curve is such that only about one-fourth of the total energy emitted from a red star lies in the visible and in the ultra-violet part of the spectrum. However, it should dispel all doubt as to the quality of the radiations emitted by red and by blue stars.

As a rough comparison, it may be stated that blue stars emit two times as much "light" as the yellow stars and three times as much "light" as the red stars. This no doubt is owing to a difference in the emissivity of the radiating layer of these different types of stars. The blue star may be at a higher temperature than the red star, but the total radiation emitted by the former may be less than from the latter, as observed in this investigation. It means that the rate of cooling of a blue star, as a result of loss of heat by radiation, is less than the rate of cooling of a red star.

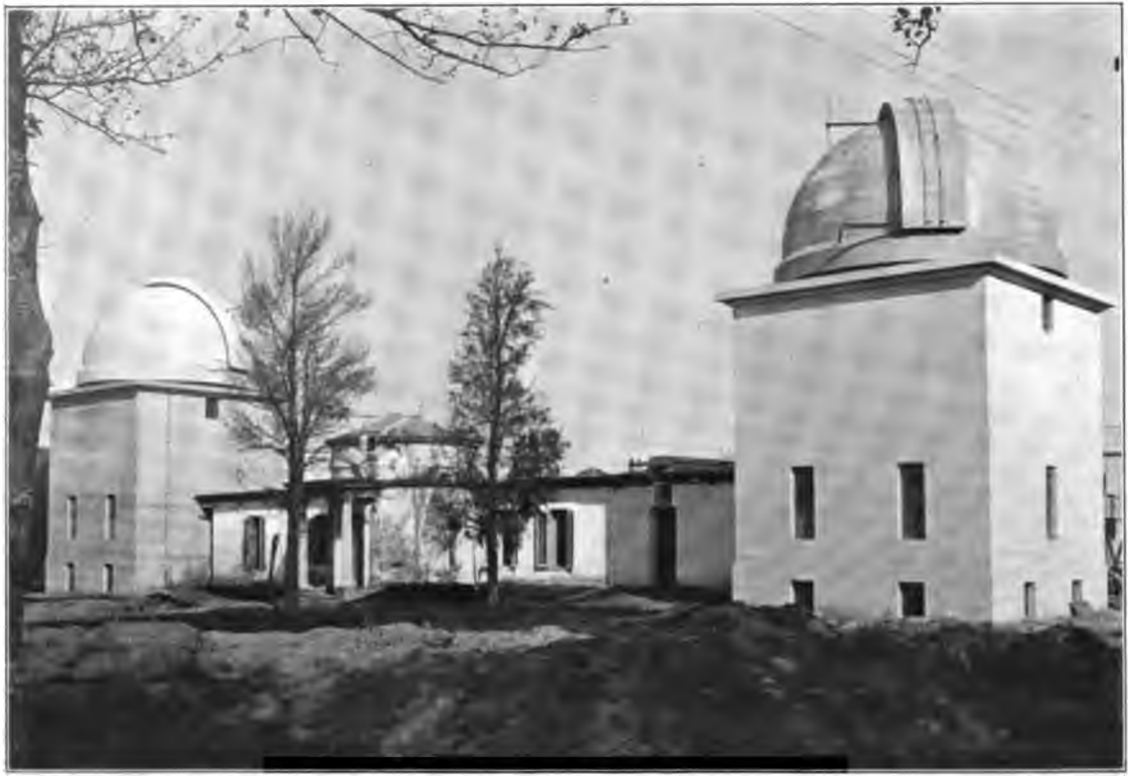
Measurements were made on the "light" reflected from the bright and the dark bands of *Jupiter*. Both gave practically the same transmission thru the water cell, showing that whatever may be the cause of the dark bands, the diminution in brightness is quite non-selective as regards the infra-red. Interesting measurements were made on *Saturn* and its rings. Measurements on a planetary nebula showed no positive indications of radiations from it. However, from the observations on blue and red stars, it was not expected that definite indications of ("heat") radiations from nebulæ would be obtained.

From 50 to 60 per cent of the light reflected from *Venus*, *Saturn*, and *Jupiter* is transmitted by the water-cell. On the other hand, only 14 to 15 per cent of the light of the Moon was transmitted by the water-cell. The explanation given is that the lunar surface becomes quite warm from exposure to the Sun and in turn radiates heat waves, which are not transmitted by the absorption cell. The albedo of the Moon being much less than that of the planets, it should become heated to a higher temperature and the transmission thru the absorption cell should be the least, as observed.

In conclusion I cannot express sufficiently the feeling of gratitude for the opportunity which enabled me to make these measurements. In a half-hearted way, at odd times during the past few years, I have constructed thermojunctions for stellar radiation measurements, but obstacles (some not entirely impersonal) would come in the way of testing them. I am therefore very grateful to my colleague, Dr. K. BURNS, whose enthusiasm kept me at the later stages in the work of construction and testing of stellar radiometers, in view of the importance of astronomy. To Mr. S. B. NICHOLSON, who operated the reflector on several nights, and to Mr. W. K. GREEN, who performed this duty during the remainder of the work, I am greatly indebted for the assistance rendered. To Dr. W. W. CAMPBELL, Director of Lick Observatory, who placed the Crossley reflector and the assistants at my disposal, and to Dr. S. W. STRATTON, Director of the Bureau of Standards, who detailed me officially to carry on the investigation, I am especially indebted for the courtesies extended.

What is needed for extending the work is evident, viz., a large reflector seven to nine feet in diameter, situated in a superb location like Mt. Hamilton as regards climatic conditions, and set apart primarily for work in stellar radiation. When one thinks of all the money wasted in idle pleasure and in the wars of nations, it seems rather ironical to discuss this matter. However, I shall retrace my steps over the 3,100 miles to renew my efforts to further increase the sensitivity of the radiation instrument, hoping that thru some opportunity, equally as unforseen as was this one, I may be enabled to continue the work.

MT. HAMILTON, CAL., August 28, 1914.



TWO NEW DOMES FOR THE CÓRDOBA OBSERVATORY.

[illegible] SCREENS FOR THE CORONA [illegible] IN WHICH THE TELESCOPES ARE [illegible] BY THE WAVES

[illegible]

[illegible]

The walls for the astrograph have just been completed. The telescope support in this case is only slightly different, but in the nature of a further improvement. The essentially different point in this support is that smaller I-beams were used and that they were surrounded by concrete, thereby obtaining greater stiffness.

Owing to the fact that the astrographic telescope rests upon two piers, the construction had to be adapted to these conditions. This was done by putting a concrete beam 110^{cm} wide and 30^{cm} thick along the middle of the room from north to south and three interlocking beams east and west underneath —one in the middle, one near the north and one near the south wall—the two latter under the feet of the two piers which support the polar axis. These east and west beams are 45^{cm} wide by 30^{cm} high.

The floors of the observing-rooms in both cases are entirely independent of these supporting beams, except that the walls finally carry both. In any situation where there are heavy winds at night there would probably be vibrations of the walls sufficient to communicate to the telescope. At this observatory, however, we never have any high night winds except during storms, when observing is impossible for other reasons, and usually the nights are perfectly still, so there was no fear of such a supporting system as that described above on account of wind.

The 12-inch telescope has now been in use in its new position for over a year and we have been able to judge of the suitability of such a method of support.

Heavy walking on the floor causes vibrations which are communicated to the telescope enough to make the image of a star vibrate two or three seconds of arc. Reasonable care, however, prevents noticeable vibration. Under the conditions in which the usual micrometer work is done, no unsteadiness whatever is noticed. I have several times observed with winds of ten to fifteen-miles velocity, but have never detected any vibrations. In the heavy storm winds there is a slight trembling. Concrete beams like those used in the astrographic dome should considerably decrease these vibrations. If they were still objectionable a slender iron column could be placed underneath the center of the beam and pier extending to the ground. This would probably practically eliminate them.

Another method of eliminating floor vibrations would be to put a moderately flexible covering over the concrete floor, such as carpet or cocoa matting.

The economy of space in the rectangular construction is very great, especially in the case of small domes. Such a form also permits of more convenient and economical arrangement of stairways, entrances, etc., in the attached buildings.

The stability of this system of support appears to be as good for locations where high winds are not prevalent, as the old form of isolated pier, especially if the telescope is at a considerable height above the ground. A modified form of this construction could be used in locations having high winds. In the matter of cost, there is a marked saving where only first-class construction is considered.

In another place[1] I have described the effect of a stroke of lightning on one of these domes.

The following details are added for the benefit of those considering similar construction:—

The foundation walls are 90^{cm} in width, resting on hard earth. The basement walls are 40^{cm} in thickness and the two main stories 25^{cm}. In the astrographic dome, owing to the two piers being so close, the north wall and the south wall are each 30^{cm} thick. The walls are 10^{m} high, including the foundation.

The ceilings of the rooms underneath the observing-rooms are without openings and are well plastered to prevent currents of air rising into the observing room.

It was found in the old astrographic dome that if the door leading from the main building was opened even for a few minutes the star images were considerably enlarged in average seeing. The practice was therefore adopted of keeping all doors and windows shut during the actual observing. The windows and doors of the new domes, including their frames, are of iron and the floors are tile or cement.

Preliminary experiments indicate satisfactory freedom from vibration.

Observatorio Nacional Argentino, Córdoba, April 3, 1914.

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[1] See these *Publications*, 26, 162, 1914.

MAXIMUM BRILLIANCY OF VENUS.

By Arthur B. Turner.

The brightness of a star, as far as we can tell, is due to the fact that it is a glowing mass in space, sending out waves of light in all directions, a small fraction of which are gathered by the lens of the eye, or the eye aided by the telescope, and give us the sense of its existence. A star may be intrinsically bright or it may be bright because it is close to our solar system.

Astronomers designate the brightness of a star by an algebraic number, which is called its magnitude. The larger the number the fainter the star. On such a scale *Polaris* is of magnitude 2.2, *Aldebaran* 1.0, Sirius —1.4, and the Sun —26.3. A star of magnitude 1 is approximately 2½ times as bright as a star of magnitude 2, which is the common ratio of brightness between any two consecutive magnitudes on down the scale.

The observations made at different times on the same star, however, often show that there is a change in the magnitude, generally very slight, altho sometimes quite large. Over four thousand such stars have already been observed. Many of these change their magnitude quite irregularly; others are periodic, repeating their maximum and minimum brightness at regular intervals, ranging from 3 hours 12 minutes to 610 days. Why the stars change in magnitude we do not know, except in those cases where the spectroscope gives additional information, showing that the star is not single but double, each star periodically partially eclipsing the other as they revolve around their common center of gravity.

Passing over the comets and meteors, the former of which, altho self-luminous, have their brightness violently altered on their approach to the Sun, and the latter of which, tho cold as outside space, become suddenly luminous from friction when they rush into the Earth's atmosphere, we come to a class of star-like bodies in the sky most of which shine entirely by reflected light—the planets and their satellites. These bodies will vary in brightness from the following causes: (a) the distance from the source of light, (b) the distance from the observer, (c) the amount of illuminated surface visible (i. e. the phase), (d) the reflecting power of the body, called its albedo, and (e) possibly the rotation of the planet or satellite on its axis, since all portions of their surfaces may not have the same reflecting power.

Next to the Moon, which is very conspicuous in her monthly changes of brightness with accompanying phases, we find the planet *Venus* changing in magnitude, but curiously reaching its maximum brightness in the crescent phase. Since the orbit of *Venus* is very nearly circular and but slightly inclined to the ecliptic, a rather simple mathematical demonstration of the above fact is possible. The principle is also applicable in the case of the other planets, but with a lesser degree of accuracy.

Let us assume, then, that the orbits of the Earth and *Venus* are two concentric circles, with the Sun as the common center. Let r be the radius of the orbit of *Venus,* ρ the distance between the Earth and the planet at any given instant, and ψ the angle at *Venus* between the Sun and Earth (see Figure 3), then the intensity (I) of the light reaching the Earth is given by the equation—

$$I = K \frac{(1 + \cos\psi)\, ½\pi a^2}{\rho^2 r^2}$$

K is a constant and a is radius of *Venus.* The numerator $½\pi a^2\,(1 + \cos\psi)$ is the area of the surface of the planet that is visible [for example, when $\psi = 0°$, $\cos\psi = 1$ and we get πa^2 as full phase; again when $\psi = 90°$, $\cos\psi = 0$, and we get $½\,\pi a^2$, or half phase; also when $\psi = 180°$, $\cos\psi = -1$, and we get 0 area or new phase]. Since light varies inversely as the square of the distance both of the observer from *Venus* and of *Venus* from the Sun, we have the product of the two squares as the denominator. But by trigonometry $\Delta^2 = \rho^2 + r^2 - 2r\rho\cos\psi$, whence—

$$I = K \frac{[(r + \rho)^2 - \Delta^2]}{r^3 \rho^3}\, ½\pi a^2$$

It is evident that for a given value of r (i. e. for each planet) there will be generally one value of ρ which will make I, the planet's brilliancy, a maximum. From this value of ρ we can easily calculate the triangle for angle ψ and hence find the phase of the planet, when it has maximum brilliancy as viewed from the Earth. This value of ρ can be obtained approximately by the method of "cut and try" (i. e. trying values of ρ until we get the largest value of ρ possible for a given value of r). The differential calculus, however, enables us to solve the problem directly, and we easily find that ρ must be a root of the quadratic equation $\rho^2 + 4r\rho + 3r^2 = 3\Delta^2$ to give a maxi-

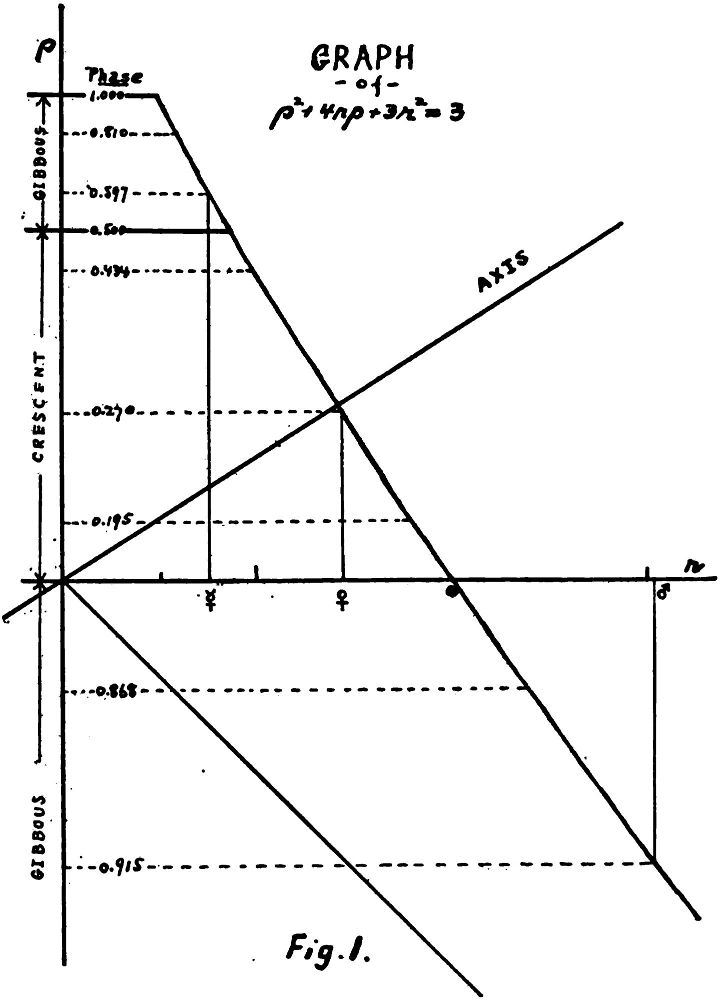

Fig. 1.

mum value of I; each value of r giving a different value of ρ. That is, in general, no two planets will be in exactly the same phase or distance from the Earth when at maximum brilliancy.

Figure 1 is a graphical representation of this equation, where Δ is taken as the unit of distance. Only a portion of one branch of the curve, an hyperbola, is shown as it is sufficient to illustrate the argument. The axis of the curve is shown and also one of the tangents at infinity—an asymptote. For nine values of ρ the phase has been calculated, and is indicated on the horizontal dotted lines by the decimal of the disk illuminated. For example: (1) *Mercury* (☿), which is at a distance $r = 0.387$ from the Sun, must be at a distance $\rho = 1.001$ from the Earth, when its brightness is a maximum. The planet will then be 0.597 illuminated, and will appear in the gibbous phase in the telescope. (2) *Venus* (♀) has $r = 0.723$, which gives $\rho = 0.431$, and 0.270 of the disk is illuminated and the planet will be seen as a crescent about like the Moon when it is between four and five days old. (3) *Mars* (♂) has $r = 1.524$, $\rho = -0.741$ and 0.915 of the disk will be illuminated, almost full phase when its brightness is at maximum. The diagram also shows that for planets with r between 0.25 and

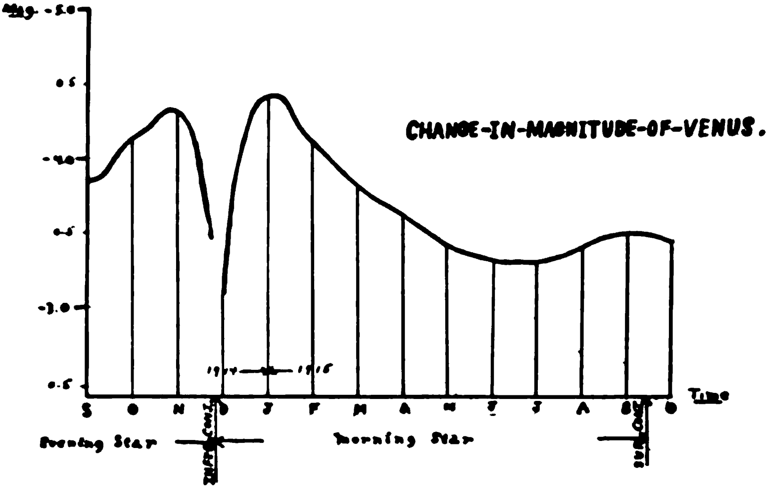

Fig. 2.

0.44 the phase is gibbous, for r between 0.44 and 1.00 it is a crescent, and for values of r greater than 1 the phase is again gibbous; that is, the farther the planet is from the Sun the closer it will be to opposition when at maximum brightness.

In order to show the rapid changes in the magnitude of *Venus*, Figure 2 was drawn from data taken from the *American Ephemeris*. Beginning with September 1, 1914, numerous dates with corresponding magnitudes have been plotted up to October 1, 1915. Thru these points a curve was drawn. The time axis was taken at magnitude —2.4, which is the maximum brilliancy of *Jupiter*, for purposes of comparison. It is noticed that *Venus* reaches a maximum (—4.4) toward the end of October, 1914, when an evening star, and again in the first part of January, 1915, when a morning star. At these two times the planet is 6¼ times as bright as the maximum of *Jupiter* and 180 times as bright as *Polaris*. The gap in the curve is during the passage thru inferior conjunction. [The phase of *Venus* and its distance

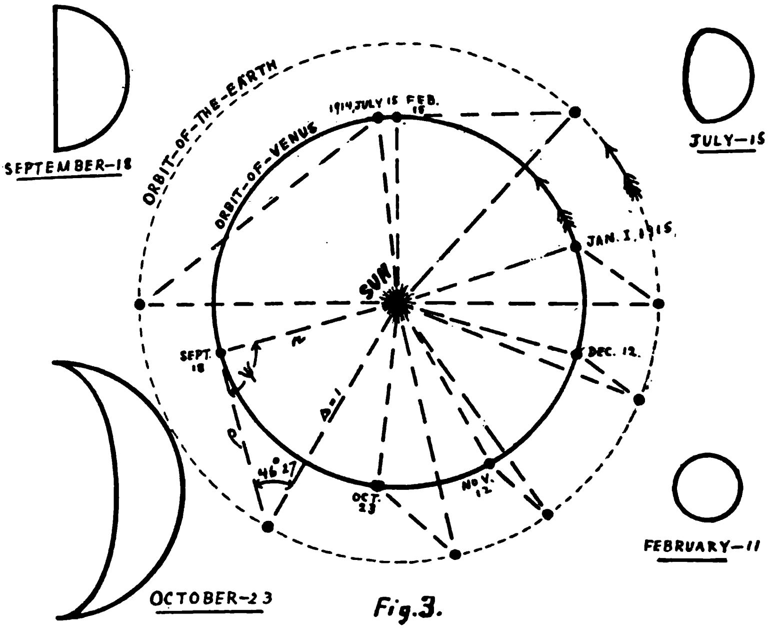

Fig. 3.

from the Earth at maximum brightness as found from Figure 1 agree very well with the more accurate values of the *American Ephemeris.*] The reflecting power of the surface of *Venus* is three times that of the surface of the Moon, and this is probably due to the fact that *Venus* is enveloped in clouds, while the Moon has practically no atmosphere whatever. In thirty-six days the planet passes from inferior conjunction to such a magnitude that it can be seen in full daylight. The maximum brightness of *Venus,* either as a morning or an evening star, is repeated every 584 days.

Figure 3 shows the relative positions of the Earth and *Venus* for seven dates from July 15, 1914, to February 15, 1915. This interval includes the two dates of maximum brilliancy. Four phases and corresponding changes in apparent diameter are also shown, the full phase of superior conjunction (February 11th) being taken as the unit. On September 18th the planet reaches maximum eastern elongation from the Sun and is just half illuminated (magnitude —4.1). [In this position the Earth, *Venus* and the Sun form a right triangle.] The sine of this angle (46° 27′), which is 0.725, gives a very good approximation to the distance of *Venus* from the Sun. On October 23d the planet is a large crescent and of maximum brightness (—4.4 magnitude). The last of November, 1914, the planet is again in line with the Sun (inferior conjunction). After this time *Venus* becomes a morning star, rising before the Sun, and then repeats the phases, reaching maximum again on January 1, 1915, and superior conjunction in September, 1915.

THE COLLEGE OF THE CITY OF NEW YORK, August 27, 1914.

THE MAGNITUDE EQUATION IN STAR TRANSITS.

By R. H. Tucker.

In accordance with previous practice, the effect of magnitude equation, or the influence of the brightness of a star upon the transit recorded by chronograph, has been recently investigated again here. The observations were made on five nights, in the month of August, and the results will be used to determine and to confirm the correction that will be applied to the transits of stars observed in the present program of meridian-circle work, which includes about four thousand observations.

The usual result of such determinations is shown in this series; nearly all observers who have investigated the correction are found to have recorded faint stars later than bright stars. The effect is determined by screening the object-glass for some transits of the brighter class of stars, and comparing the recorded transits with those of the same stars, when observed full brightness. The screen was applied with the help of volunteer assistants, as in the earlier series. The screen used in this series reduces the brightness by nearly four units of magnitude (3.95 ± 0.05), the reduction being derived from the difference between the full brightness and the estimated magnitude when the screen has been applied. For the magnitudes of the stars, the Harvard photometric magnitudes have been adopted, tho these do not differ much from the values given in the *Berliner Jahrbuch,* the photometric scale being 0.1 fainter for the mean, with an average difference of ± 0.15 between the two scales. The stars selected range in brightness from 0.1 to 6.3, but the reduction due to the screen appears to be less for the faintest stars observed than for the brighter classes. Up to third and fourth magnitudes, the reduction is estimated in excess of four units; while the stars of fifth and sixth magnitudes are reduced by less than four units, according to the estimates made at the time of transit. This apparent discordance may be due to a difference between the adopted visual scale of magnitudes, and a scale that would be exactly

[illegible]

[illegible]

[illegible]

[illegible]

difficult to change this estimate in practice, even if the magnitudes of the existing star catalogs could be adjusted to a scale more in conformity with late photometric measures.

In its effect upon the present results of magnitude equation, this possible discordance does not produce errors of any serious amount, for the total effect of the screen upon transits, derived for stars of estimated brightness, is in accord with the usual visual scale for stars of those types. In dividing the total effect by the reduction due to the screen, a small uncertainty in the reduction per unit of magnitude may be introduced; but there already exists some doubt as to whether the reduction is the same for some observers at all points of the scale. That is, for some observers the difference in transits between a second and sixth magnitude may be quite different from the difference in transits between a fifth and a ninth magnitude. This present series has been tested for such a variation, but has been found to give fairly uniform values of the magnitude equation, for the different classes of bright stars reduced by the screen.

These values are: a difference of $0^s.027$ for south stars, or $0^s.007$ per unit of magnitude; and $0^s.031$ for stars north of the zenith, or $0^s.008$ per unit of magnitude. Twenty-four stars south of the zenith were used, and twelve stars north of the zenith, on the same five nights. By using five nights, the differential values can be taken out in reverse order for the pairs of adjoining nights, giving four determinations of magnitude equation, well balanced in respect to accidental effects of combination. The five nights, then, give a weight of sixty determinations south of the zenith, and a weight of thirty north. The probable error of a single determination of the full difference due to screen is $\pm 0^s.030$ for south stars and $\pm 0^s.026$ sec δ for north stars. The probable error of the mean result does not much exceed $\pm 0^s.004$ in either case, and the probable error per unit of magnitude is $\pm 0^s.001$ sec δ. The values from stars on both sides of the zenith are nearly the same, tho some variation might be anticipated, and in fact is often found to exist, for various observers.

Explanation of a variation would be involved in the general explanation of the cause of the correction for magnitude equa-

[illegible] there is a difference in the [illegible] [illegible] the direction of the motion of the star in [illegible] a star appears to move from [illegible]

[illegible]

Except for some diffraction rays, for the very brightest stars, which do not interfere with precise observations of the central image, the image of a screened star is quite exactly like that of a star of fainter class. The screen is made of very fine wire netting, most carefully constructed for uniformity of spacing, and four thicknesses are used in the screen that gives a reduction of about four units of the magnitude scale.

To illustrate the consistency of the magnitude equation, and for a record of the results to date, the earlier determinations are tabulated here. They include those made at the San Luis Observatory of the Carnegie Institution, in the years 1909 and 1910, when the observations were taken with the meridian circle belonging to the Dudley Observatory at Albany, the object glass of which is eight inches, while ours is 6.4 inches, at Lick. At the southern station, in the Argentine Republic, it is to be noted that the clock stars and the rapidly moving stars in general were north, while here the same class of stars are south of the zenith. In the larger and older instrument, there are three sets of transit threads, of nine wires each, so that a determination of magnitude equation can be made at one transit, by screening either one or two of the sets. With our single group of threads, it requires the comparison of results upon two nights to give a determination. This present series is the second one taken since my return, and such a record of alternation with two instruments, and with the variety of conditions, can not often be obtained. Notwithstanding some variations in the results for different years, the magnitude equation is evidently nearly constant, with a slight difference in effect depending upon the direction of motion.

LICK OBSERVATORY MERIDIAN CIRCLE.

South stars—

Year.	No.	Mag. Eq.
1896	75	—0^s.009
1898	60	—0 .006
1902	48	—0 .006
1907	49	—0 .010
1911	45	—0 .010
1914	60	—0 .007
Mean		—0^s.008

North stars—			
1907		41	—0s.025
1911		20	—0.0[illegible]0
1914		30	—0.008
Mean		.	—0s.0[illegible]
SAN LUIS OBSERVATORY			
South stars	1909-1910	300	—0s.0[illegible]
North stars	1909-1910	300	—0.015

A transit micrometer, one of the advantages of which is the claim that the magnitude equation is eliminated, has been ordered for the Lick Observatory. A test of the claim of freedom from this effect will be to observe for the magnitude equation, precisely as has been done with the present method. The European war will prevent the dispatch of this construction for our use at the time specified, and it may be some length of time before we can receive it and put it into service. The fact that my own magnitude equation is so well determined, for chronograph transits in the usual way, will aid in a definite test of the new construction. It would not be enough, for instance, to show simply that no effect is left when the transit micrometer is used; it is necessary to show that the effect existed, for a special observer, without the use of the traveling thread.

For illustration of the variety of magnitude equation, for separate observers, there are tabulated below the condensed results for the five observers who did transit work at San Luis, taken from the *Carnegie Year Book*, 1911, page 1[illegible]0:—

	North	South
R. H. Tucker	—0s.015	—0s.010
A. J. Roy	—0.015	—0.003
W. B. Varnum	—0.010	—0.003
M. L. Zimmer	—0.011	—0.008
R. F. Sanford	—0.005	—0.010
Means	—0s.011	—0s.007

August 31, 1914.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1914.

BY MALCOLM MCNEILL.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon	Nov. 2,	$3^h 49^m$	P.M.	Full Moon	Dec. 2,	$10^h 21^m$	A.M.
Last Quarter	" 10,	3 37	P.M.	Last Quarter	" 10,	3 32	A.M.
New Moon	" 17,	8 2	A.M.	New Moon	" 16,	6 35	P.M.
First Quarter	" 24,	5 39	A.M.	First Quarter	" 24,	12 25	A.M.

The Sun reaches the solstice and begins again its northward journey among the stars December 22d at about 8 A. M. Pacific time.

Mercury will be in transit across the Sun's disc on the morning of November 7th. Transits of *Mercury*, while not frequent, are much more so than transits of *Venus*, there being twelve in the present century. As they must occur when *Mercury* is near one of its nodes and the Earth also near the line of *Mercury's* nodes, there are two periods each year, early May and early November, during which all transits must occur. Also on account of the eccentricity of the planet's orbit November transits are more than twice as numerous as May transits. After a November transit another is possible in seven years, probable in thirteen years and practically certain in forty-six years. The present one is an instance of the first, there having been a November transit in 1907. Only the latter part of the present transit can be seen in this country, and in some parts none of it, the ingress taking place before sunrise. The principal circumstances are as follows, Pacific time:—

Ingress exterior contact	Nov. 7,	$1^h 57^m 14^s$	A.M.
Ingress interior contact	" 7,	1 59 27	A.M.
Least distance of centers 10′ 31″	" 7,	4 3 20	A.M.
Egress interior contact	" 7,	6 7 17	A.M.
Egress exterior contact	" 7,	6 9 31	A.M.

It will thus be seen that in the far west the entire transit is over before sunrise, but that the latter part of it may be observed in the central and eastern parts of the United States. A telescope is necessary to show the planet on the disc of the Sun.

After the transit, which occurs at the time of inferior conjunction, *Mercury* becomes a morning star and moves out toward greatest west elongation, reaching this position on November 23d. Before the middle of the month it will rise more than an hour before the Sun, and the interval will not be less than an hour until nearly the middle of December. About the time of greatest elongation the interval will be more than an hour and a half. There will therefore be a month when the planet can be seen in the morning twilight. It will be in close conjunction with *Venus* on the morning of December 7th, the nearest approach being about two thirds the diameter of the Moon, *Mercury* being north of *Venus*. At the end of the month *Mercury* has nearly reached superior conjunction with the Sun.

Venus is still an evening star on November 1st, but sets about an hour and a quarter after sunset. On November 27th it passes inferior conjunction with the Sun, becoming a morning star. On account of the fact that the planet is moving northward among the stars much more rapidly than the Sun is, the interval between the rising of the planet and of the Sun will increase very rapidly. By the middle of December the planet will rise more than two hours before sunrise, and there will be an additional increase of an hour by the end of the month. *Venus* will remain a morning star until September 12, 1915. After conjunction its brightness increases very rapidly and by the end of December it has nearly reached its maximum. This occurs January 2, 1915.

Mars is too near the Sun during November and December for naked-eye view. On November 1st it sets only forty minutes after sunset, and this interval continually diminishes until the planet reaches conjunction with the Sun at 9 P. M. Pacific time on December 23d. It then becomes a morning star and remains such until the next opposition. This does not occur until February 9, 1916. The interval from opposition on January 5, 1913, to conjunction is only 352 days, while from conjunction to the next opposition will be 413 days.

These intervals would be equal if the orbits of Earth and *Mars* were both circular. It is an unusual occurrence that an opposition and a conjunction occur in the same calendar year and neither in the year following. The average interval from opposition to conjunction is 390 days, nearly one year and one month.

Jupiter is in good position for evening observation in the southwestern sky. On November 1st it sets a little before half-past eleven and at the end of December shortly after 8 P. M. It is in the eastern part of the constellation *Capricorn* and moves about 9° eastward and 3° northward among the stars during the two months. It is in close conjunction with the Moon on the night of November 22d-23d and again on the evening of December 20th. It will be occulted on the latter date for some regions of the Earth.

Saturn is in good position for evening observation during the latter part of the two months' period. On November 1st it rises shortly after 8 P. M. and a little before sunset at the end of December. It comes to opposition with the Sun on the night of December 20th-21st. It is on the border-line between *Taurus* and *Gemini* and moves somewhat more than 4° westward during November and December. The appearance of the rings remains practically unchanged.

Uranus is in the southwestern sky in the evening, setting shortly before eleven on November 1st and shortly after seven on December 31st. It is in the constellation *Capricorn* and moves about 2° eastward. It lies to the west of *Jupiter* about 6° on November 1st, but this distance is nearly doubled by the end of December.

Neptune rises shortly after 10 P. M. November 1st, and shortly after 6 P. M. on December 31st. It is near the border-line of the constellations *Gemini* and *Cancer* and moves about 1° westward.

additional photographs before the true one could be selected, for altho the two hyperbolic orbits were recognized as exceedingly improbable, the problem in hand demanded not only the proof that the elliptic orbit would satisfy future observations, but also that the other two orbits were impossible. Positions were computed from the ellipse for August 21st and 23d, and at that time I went to Mount Hamilton to secure further observations. The object was found very near the predicted place on the three nights of August 21st, 22d and 23d.

Of the three orbits the ellipse around *Jupiter* was the only one that represented these observations satisfactorily, thus proving the ellipse to be the real orbit, and establishing the identity of the object as a newly discovered satellite of *Jupiter*. The fact that this identity could be established without previous assumptions by LEUSCHNER's method, particularly from observations so close together—the entire interval for the original solution being only nine days—shows the remarkable efficiency of the method. The elements of the orbit are of course only approximate, but they serve to establish the identity of the object and to describe the nature of the orbit, which is very similar to that of the eighth satellite. The motion is retrograde, and the period about three years. A detailed account of the discovery and the orbit computation will be published in the Lick Observatory Bulletin. SETH B. NICHOLSON.

UNIVERSITY OF CALIFORNIA, September 17, 1914.

AN A-TYPE STAR OF VERY LOW LUMINOSITY.

It has been suggested by HERTZSPRUNG that there is no such range in absolute brightness among the A-type stars as among those of types F to M, and, in fact, it is doubtful whether hitherto any certain case of a very faint A-type star has been found. A recent observation of the ninth-magnitude companion of *o Eridani* shows, however, that this star must be considered as such. The companion is at a distance of 83″ from the principal star and shares in its immense proper-motion of 4″.08 annually. Its parallax, therefore, may be assumed to be that of the bright star which is 0″.17. This would make the absolute magnitude of the companion 10.3, the Sun being taken as 5.5. The spectrum of the star is A0.

WALTER S. ADAMS.

THE ALTITUDE OF MOUNT HAMILTON.

During a study of the meteorological record kept by the Lick Observatory the attention of the writer was directed to a difference in the altitude of Observatory Peak as stated by different authorities. The following statements of the altitude of the mountain have been made, all referring to the marble floor of the main building:—

Altitude above mean sea level.	Stated by	Reference.
4209.46	Director HOLDEN	*A. S. P. Publ.*, 3, 370.
4209	U. S. Geol. Survey	Mt. Hamilton Sheet
4209	U. S. Geol. Survey	Bull. 274, p. 96.
4209	U. S. Wea. Bureau	Climatological Data for California.
4221	U. S. C. & G. Survey	Transcont. Trian., Spec. Publ. No. 4, p. 304; An. Rept., 1910, p. 398.

The first four of these statements are probably all the result of a line of precise levels run from the Southern Pacific track at the Market Street Station in San Jose in 1887 by a party of students of the College of Civil Engineering of the University of California under the direction of Mr. W. G. RAYMOND. The results of this survey were published in Volume III of these *Publications*. In a letter dated July 8, 1914, Professor RAYMOND states that "the elevation of the track at San Jose was gotten from the [Southern Pacific] Company. . . . The work was spirit leveling and its precision was pretty fairly close; . . . the probable error . . . was a very small fraction of a foot." The elevation given for the Market Street Station was stated in the report of this survey as 88.7 feet. The chief engineer of the Southern Pacific Company has informed the writer that the Market Street Station has not been changed since 1887. The elevation of the base of the rail at the station appears on the present railroad profile as 85.7 feet above the "S. P. zero," which is 5.7 feet above the datum plane of the United States Coast and Geodetic Survey, the mean of the lower low-waters. Mean sea-level at Goat Island, which is the nearest tide station to Oakland Pier, where the "S. P. zero" was compared with the Coast Survey datum plane, is about 3.4 feet above the Coast Survey datum plane. This makes the level of the track at the San Jose Market Street Station 88.0 feet above mean sea-level.

The discrepancy of 0.7 foot is not much greater than the difference between other precise level determinations in San Jose. For example, the elevation of the United States Geological Survey bench mark on the Hall of Records at the southwest corner of Saint James and First Streets. This bench mark has been determined by the Geological Survey as 98.317 feet above mean sea-level from a line of precise levels run from tide water and forming a closed circuit.[1] The same bench mark has been determined by the Coast and Geodetic Survey as 98.097 feet in the precise level net for which the results are not yet published.

The altitude of Mount Hamilton is stated in the "Dictionary of Altitudes in the United States," published by the United States Geological Survey, as 4209 feet; the authority for this altitude is the Geological Survey. The statement in regard to this authority is as follows:—

> A vast number of elevations are credited to this source. They have been determined by various means, but almost entirely by trigonometric methods and by level lines. Elevations of mountains, hills, and other points used as triangulation stations have, as a rule, been determined by trigonometric methods.[2]

The Mount Hamilton sheet of the Topographic Map of the United States, which is being issued in sheets by the Geological Survey, shows the altitude of Observatory Peak as 4209 feet. This sheet was surveyed in 1895 and the triangulation is stated as by the Coast and Geodetic Survey. In regard to the altitudes on this sheet the Topographic Branch of the Survey writes as follows:—

> The Mount Hamilton quadrangle was completely surveyed before Congress authorized the Geological Survey to run level lines and establish bench marks; consequently there were no bench marks set within that area.

The altitudes published by the Weather Bureau for its co-operative stations rest on data furnished by the co-operative observers when the stations are established and, therefore, the statement of 4209 feet by this authority must be regarded simply as a publication of the altitude determined by the Raymond party in 1887.

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[1] See Bul. 342, U. S. Geol. Survey, p. 126. Also Bul. 481, p. 66.
[2] U. S. Geol. Survey Bul. 274 (1906), p. 11.

The altitude of Mount Hamilton was determined by the United States Coast and Geodetic Survey by trigonometric leveling. The altitude is stated as 1298.9 meters (4262 feet) on top of the twelve-inch dome.

> The height of the small [12-inch] dome above the marble floor of the observatory is stated to be 40 feet 4 inches (12.3 meters); hence the height of the marble floor is 1286.6 meters or 4221 feet.[1]

In a letter dated June 19, 1914, the acting superintendent of the Survey states that—

> the elevation of Mount Hamilton, although placed in class 3 in "Triangulation in California, Part II," meaning that it was determined from non-reciprocal observations, has a probable error very much smaller than ten meters. This elevation was determined by vertical observations at five stations, at each of which there were observations on several days. The probable error of the elevation of Mount Hamilton, as contained in "Triangulation in California, Part II," is approximately one meter. The point determined was the top of the dome, as it existed in 1883-85.[2]

There seems to be no way at this time in which the two different altitudes for the mountain can be reconciled, nor any information which would cause the rejection of one or the other. Altho the line of precise levels was student work, Professor RAYMOND states that the probable error was very small and there is hardly any possibility that it could be as great as ten feet in the thirty miles from San Jose to the Lick Observatory. On the other hand, an error of this amount in the work of the Coast and Geodetic Survey is fully as difficult to understand. Precise levels were run to the top of Mount Diablo during the work of the Transcontinental Triangulation for the purpose of determining the value of refraction; this, together with the large number of observations, makes such an error seem out of the question.

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[1] The Transcontinental Triangulation by Charles A. Scott, U. S. Coast & Geod. Survey, Special Publication No. 4 (1910), p. 304. Also Triangulation in California, Part II, Ann. Rept. Supt. U. S. Coast & Geod. Survey for 1910, Append. 5 (1911), p. 398.

[2] This is the 12-inch dome, the 36-inch dome was not built at that time.

The altitude of Mount Hamilton is certainly just over 4200 feet, probably between 4209 and 4224. For practically all purposes this is as close as is necessary for actual use, altho it would be interesting to know the exact height of the mountain.

WILLIAM G. REED.

BERKELEY, CAL., September 3, 1914.

COLOR VARIATION OF THE CLUSTER-TYPE VARIABLE RS BOÖTIS.

The very sudden and rapid increase in the brightness of cluster-type variables after the gradual decline to minimum suggests, if it does not demand for its explanation, some disturbance in the stellar atmosphere. Such a disturbance would almost certainly be accompanied by changes in the color of the light radiated by the star.

The matter has been put to a test in the case of the variable RS *Boötis,* whose period is 9^h 3^m and whose visual amplitude of variation, as shown by unpublished Laws Observatory observations, is approximately one magnitude. To avoid the influence of possible fluctuations in the light-curve, ordinary and isochromatic plates (the latter used with a yellow filter) were alternately exposed on three successive nights — July 16, 17 and 18, 1914—the instrument used being the 60-inch reflector. The exposures were, respectively, one minute and two minutes on the two kinds of plates. Five or six were made on each ordinary plate, and three or four on the isochromatic plates. A total of 85 plates and about 350 separate exposures cover the entire curve, with sufficient overlap from night to night to test the possibility of systematic differences between the three series of observations.

Five comparison stars covering an interval of about 2.5 magnitudes are available for the reduction of the measures of the variable. Their magnitudes on an absolute scale were established by varying the aperture for the different exposures. The apertures used were 32, 14 and 9 inches for the ordinary plates, and 60, 40 and 32 inches for the isochromatic plates.

Both the photographic and the photovisual scales were separately derived from the data of two nights. The difference in the magnitudes of the comparison stars for the two nights are:

Star	1	2	3	4	5
Photographic	+0.06	−0.04	−0.01	−0.06	0.00 magnitude
Photovisual	−0.03	+0.04	−0.02	+0.01	−0.06 magnitude

In each case the faintest star—No. 4 for the photographic scale and No. 5 for the photovisual—was disregarded in reducing the results for the different plates to a common zero point. This accounts for the fact that the sums of the differences do not in either case equal zero.

With the aid of the mean scales for the two nights, the entire series of observations on the variable was reduced to a uniform system. The results for each plate were combined to form a mean value, which, in spite of the rapid change in brightness, is justifiable since the interval covered is only six or eight minutes. There are thus available for the formation of the light-curves 83 points (two plates were rejected), 43 for the photographic light-curve and 40 for the photovisual.

It was found that the photographic range is nearly 50 per cent in excess of the photovisual. For the present the amplitudes may be taken as 1.5 and 1.1 magnitudes, respectively. The change in the color index is therefore about 0.4 magnitude, which corresponds to about one spectrum class. The limiting values of the color index cannot now be given, as the zero points of the magnitude scales are still to be determined. The probable values, however, can be assigned on the basis of the spectroscopic results by PEASE. He finds that the spectral type of the star is constantly changing, with limiting values of B8 and F0, respectively, for maximum and minimum. The corresponding color indices on the scale of PARKHURST are −0.10 magnitude and +0.40 magnitude. The spectroscopic and photometric results, in so far as the amount of change in color is concerned, are therefore in close agreement.

The variable was observed during increasing light upon two successive nights. The computed interval separating corresponding epochs is therefore three periods or 27^h 10^m. That actually observed is 27^h 12^m, which illustrates the precision with which the instant of a given brightness on the ascending branch of the curve can be determined.

The epochs of photographic and photovisual maxima appear to coincide.

The period of $9^h\ 3^m\ 21^s.57$, assigned by PRACKA,[1] represents the observed maximum on July 17th exactly. Finally, it may be remarked that the photovisual amplitude is in good agreement with that found visually at the Laws Observatory.

F. H. SEARES and HARLOW SHAPLEY.

MT. WILSON SOLAR OBSERVATORY, August 18, 1914.

THE STAR CLUSTER N. G. C. 6760.

The object N. G. C. 6760 has been suspected as variable, but DREYER in a note in the N. G. C. states that there is no reason for supposing this to be so.

BORRELLY's note in *C. R.*, **157**, 385, leads one to suppose that the object is changing in brightness, and it was accordingly placed on the observing program of the 60-inch reflector.

Two photographs were obtained on Seed 27 plates, with exposures of ¾ and 1½ hours respectively. The 1½-hour photograph revealed a star cluster lying in a rich region of the Milky Way. A single count of this plate was made with a reseau having squares 30″ on a side and the results plotted. It proved to be a cluster of 1,200 stars, 7′ in diameter, lying on a background with a density of fifteen stars per square minute. The greatest number of stars counted in a single square of the reseau was 71, which would make 67 for the cluster. Mr. SEARES estimates that the stars in the cluster lie between 16.5 or 17 and 19.5 photographic magnitude.

No trace of nebulosity is found.

Under a power of 300, which was as much as the seeing would permit, the cluster appeared granular, but save for a few of the brighter stars was not certainly resolvable.

A comparison of the two plates under the stereocomparator gave no indication of variability.

FRANCIS G. PEASE.

MT. WILSON SOLAR OBSERVATORY.

SPECTRA OF STARS IN THE HERCULES CLUSTER M 13.

An additional photograph of Messier 13 was obtained with the focal plane spectrograph of the 60-inch reflector, using a slit width of 0.050^{mm} and an exposure of thirty hours.

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[1] *V. J. S.*, 1913, p. 290.

The slit was set 3′ south of the star Scheiner 373, which Barnard uses as his normal star, and stars are scattered over a distance of 4′ in an east and west line. Identification of twenty spectra is possible, though several are composite of several close stars. Spectra of some stars of Barnard visual magnitude 15 are included.

Taking as units five divisions of the Harvard scale, these stars are classified as follows:—

Ao = 1
A5 = 6
Fo = 9
F5 = 3
Go = 1

The mean of this determination is practically the same as that given by the nineteen stars mentioned in Volume XXV, page 260, of these *Publications*.

The two results combined, making a total of thirty-nine stars, give the mean class of the cluster as Fo.

Francis G. Pease.

Mt. Wilson Solar Observatory.

Note on the Binary Star A 570.

In 1903 the star B. D. + 27°.2388 was found to be a close double. From the magnitude (5.90, Class A spectrum in *R. H. P.*) and the small angular separation, it was reasonably certain that the pair was a binary system, and the fact that the proper-motion was well defined, amounting to 0″.088 in 236°.8 according to Boss, confirmed this conclusion.

Subsequent measures have shown that the angular motion is rapid and it is probable that the period of revolution will be short, possibly in the neighborhood of twenty years.

The mean results of my measures are as follows:—

1903.40.............	198°.6	0″.20	4	nights,	36-inch
1906.41.............	173 .0	0 .24	3	"	"
1907.52.............	166 .8	0 .24	2	"	"
1911.45.............	128 .3	0 .22	3	"	"
1914.58.............	88 .5	0 .16	2	"	"

R. G. Aitken.

August, 1914.

NOTE ON COMET *c* 1914 (NEUJMIN).

The third comet of the year was discovered by NEUJMIN at Simeis on the 27th of June. An orbit based upon Dr. AITKEN'S observations of the 2d, 16th and 30th of July was derived by Mr. C. D. SHANE and the writer. The most interesting thing about the orbit is the great perihelion distance, which amounts to 3.74 astronomical units, i. e. 348 million miles. The comet made this nearest approach to the Sun on July 24th. It is moving in an orbit plane inclined 71° to the plane of the ecliptic.

On account of its great perihelion distance (which is the second largest known) its heliocentric motion is small, so that it will probably be within reach of large telescopes for several months. On this account an ephemeris is given in *Lick Observatory Bulletin* No. 260, extending to the end of this year. Comparison of this ephemeris with an observation made by Dr. AITKEN on the 26th of August shows the following representation: (O–C) $\Delta\alpha = -1^s.9$ and $\Delta\delta = +20''$. At present the comet is moving slowly toward the northeast thru *Ophiuchus.* It will cross the equator in right ascension $17^h\ 32^m$ on the 24th of September. It is nearly four astronomical units distant from the Earth so that it can be seen only with fairly large telescopes.

R. T. CRAWFORD.

BERKELEY ASTRONOMICAL DEPARTMENT, September 14, 1914.

SOME FEATURES OF THE SPECTRA OF IRON AND CHROMIUM IN THE VACUUM ARC.

The arc burning in a partial vacuum is known to give greater sharpness to the spectrum lines in general and greater strength to the enhanced lines, as compared to the arc in air. Other effects due to the altered character of the discharge have been noted in the few investigations made with this source.

The writer has recently arranged a set of fittings for a vacuum arc which may be used when desired in the chamber regularly employed for the electric furnace. The arc electrodes are controlled by hand by means of rods passing thru stuffing boxes in the end of the steel chamber. Preliminary observations have been made with iron and chromium arcs chiefly for the purpose of testing whether the differences observed between the spectra of the furnace in vacuum and the arc in air are due in any large degree to the difference in pressure of the two sources.

The photographs, taken with the first and second orders of a 15-foot concave grating, show that while differences in relative intensity occur between the arc in vacuum and in the open air, these are not in the direction of greater similarity to the furnace spectrum, but indicate rather stronger arc conditions for the vacuum arc, as would be expected from the ability of this source to bring out metallic enhanced lines.

The sharpening effect of the vacuum arc is very decided, however, for certain chromium lines which are very diffuse in the arc in air. Such lines are rendered sharp by the vacuum furnace, and the effect is apparently due to the reduced pressure employed. Perhaps the most striking cases are three very diffuse lines given in the violet region by the arc in air. The only measures attempted of these have been made by EXNER and HASCHEK, who give the wave-lengths to one decimal place. The vacuum arc and also the furnace in vacuum show two of these lines to be each composed of three lines, the intensity gradation of the group accounting for the appearance of the line in the arc in air, where the components widen and blend together. The third of the diffuse lines narrows to a single line the vacuum arc. The sharpness attained is sufficient to allow almost the same precision of measurement as is given by the ordinary arc lines.

The following measurements were made of these lines on a vacuum-arc plate, the dispersion being $1^{mm} = 1.86$A. The values are referred to adjacent lines measured by EXNER and HASCHEK:—

Arc in air (EXNER & HASCHEK)	Vacuum arc.	Nearest solar line, element and intensity (ROWLAND).		
4098.0............	4097.80	4097.808	..	0
	4098.11	4098.115	..	0
	4098.33	4098.335	Fe	5
4111.1............	4111.02	4111.021	Mn	1
	4111.51	4111.509	Ce?	1
	4111.82	4111.827	..	00
4129.4............	4129.36	4129.337	Ce–	3

It is seen from this table that a solar line occurs with a wave-length agreeing closely with each of these chromium lines. Some of them are given by ROWLAND as due, at least in part, to other elements in the Sun. If these chromium lines are really present in the Sun, it would mean that the conditions of the solar atmosphere are capable of sharpening lines in a way accomplished in the laboratory by a vacuum source.

The arc between iron terminals in vacuum presents some interesting features. A pink glow surrounds the point on the positive pole from which the arc proceeds. Towards the negative pole the vapor is bluish green, with an absence of the yellow envelope given by iron oxide when the arc burns in air. This negative glow gives the iron arc lines strongly, while the discharge at the positive pole is especially effective in giving the spectra of hydrogen and nitrogen, probably supplied by the residue of air in the chamber. The reddish glow is due to a high intensity of Hα. Bathed plates covering the region from λ 5000 to λ 6700 show Hα several times as strong as the brightest iron line in this range, which includes the brilliant arc lines of the green-yellow, a region to which the plate is more sensitive than to Hα. The line Hβ, which appears on other plates, is faint relatively to neighboring iron lines, the vacuum arc appearing to give a strong intensity gradient between the two members of the hydrogen series. At the negative pole, Hα may be detected, but is very faint.

In the violet and blue, the spectrum given near the positive pole of the iron arc is dominated by the nitrogen bands belonging to the second positive group of DESLANDRES. A similar phenomenon was noted by HAGENBACH for the copper arc in vacuum. The bands are strong and the dispersion employed gives a good resolution of the component lines. The weakness of the iron lines at the positive pole is very pronounced, the exposure time required for these being about fifty times as great as at the negative pole.

ARTHUR S. KING.

MT. WILSON SOLAR OBSERVATORY, September 16, 1914.

NOTE ON THE SYSTEM OF EPSILON HYDRÆ.

The object of this note is to call the attention of astronomers interested in measures of radial velocity to the fact that the stars A and B in the system of ϵ *Hydræ* are now approaching the line of nodes. According to my elements,[1] the star B will pass the ascending node in April, 1915. Since the date of periastron is 1916.27, only a year later, the orbital velocity is now very rapid and the companion will traverse 180° of true anomaly and reach the descending node by April, 1917.

It follows that a series of spectrographic measures beginning at the present time and extending over the next three years will give both the maximum and the minimum radial velocity of the brighter star A, and be of the greatest service in correcting the orbit elements.

ε *Hydræ*, it will be remembered, is at present the only binary system whose elements can be determined both by micrometer measures and by measures of radial velocity. Measures which I secured on two nights with the 36-inch telescope gave the position: 1914.26 265°.4, 0''.20, in good agreement with that predicted by my orbit. The angular distance is diminishing rapidly and will reach the minimum of about 0''.08 early in 1916. It will hardly be possible to secure reliable micrometer measures after April, 1915, until the companion is near the descending node in 1917. This fact adds to the importance of securing good measures of the radial velocity in that interval.

R. G. AITKEN.

September, 1914.

THE BRIGHT-LINE STAR A. G. C. 22748.
($\alpha = 16^h\ 44^m.5;\ \delta = -41°\ 4'$.)

This star was discovered to have bright lines in its spectrum by Mrs. FLEMING in 1889 from the study of the Harvard College Observatory objective-prism plates taken at Arequipa, Peru. When the designation "fifth type" was suggested by PICKERING in 1891 for the thirty-three bright-line stars then known, he placed this star in the second of three divisions, differing as to the widths and intensities of the lines, and remarked that the lines appeared to be *Orion* lines, bright instead of dark. The star is included in the list of Wolf-Rayet stars observed in 1894 by CAMPBELL, who noted the bright lines at 4600 A and 4637 A and the bright borders to Hγ 4340 A and He 4473 A. In 1898 Harvard College Observatory reported the presence in the star's spectrum of the additional dark hydrogen lines Hζ′, Hε′, Hδ′, Hγ′, and a "bright double band" at 4633 A. Miss CANNON's classification of 1900 places it in Class Oe, which is characterized by the two bright bands 4633 A and 4688 A, numerous dark lines, the strongest of which are those of the hydrogen series from Hβ to Hθ, the additional hydrogen series Hγ′, Hδ′, Hε′, Hζ′, which were first found in *ζ Puppis,* and the helium lines 4026 A, 4120 A, 4471 A, 4712 A. Her descriptive remarks are: "The bright band 4688 is half as wide and half as intense as in A. G. C. 9311, the typical star. Hβ is faint and dark and bright on red edge. Line 4514.5 A is bright on violet edge. A bright line is present at 4490 A. Band 4633 A is widely double." Lastly, the star is included in the list of fifth-type stars in Mrs. FLEMING's collection of *Peculiar Spectra,* dated 1912, with the remark: "Band 4633 A is double."

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[1] See *Publications A. S. P.*, 24, 216, 1912.

A more detailed study of this star than has previously been published is presented in the recent *Lick Observatory Bulletin,* No. 257. It deals with the results of the measures of three plates taken with the two-prism spectrograph of the D. O. Mills Expedition at Santiago, Chile, on the dates 1908 July 20, 1910 July 30, 1912 August 12. The measures of the helium line 4471.676 A on each plate gives a velocity of between 50 and 60 kilometers toward the Sun. Nearly all the lines and bands visible on the plates are identified with previously announced stellar wave-lengths. Six bright lines and three dark lines were measured and their wave-lengths deduced. These wave-lengths and descriptive notes for all the lines and bands are given in tabular form in the *Bulletin.* The particular points which have not before been noted are: The pair of lines at 4634.7 A and 4641.8 A appear as two unrelated lines, rather than as a "double 4633 A." The dark line at 4514 A is probably bright on the red edge at 4517.2 A, rather than on the violet edge, since the bright line at 4504.7 A appears farther from the dark line than that at 4517.2 A. An inconspicuous bright line appears at 4486.3 A and may possibly be a bright border to a very faint and broad absorption band at about 4482 A. The hydrogen lines Hγ and Hδ are bright on the red edge, as well as Hβ, which alone is bordered in the typical star of Class Oe,—namely, A. G. C. 9311. As in the latter, Hβ is not so strong as Hγ and Hδ. Slight brightening is present on the red edge of Hγ', 4542.1 A, and He 4471 A, but it is presumably not as conspicuous as in A. G. C. 9311 and A. G. C. 22843, respectively. The bands 4634.7 A, 4641.8 A, and 4686.3 A are each about 3.5 angstroms in width. The first two are equally intense and somewhat stronger than 4686.3 A. The two dark lines at 4089 A and 4096 A have recently been ascribed by Miss CANNON to argon.

The distinctive features of this star's spectrum are the several bright lines or bands which are characteristic of the Wolf-Rayet stars, the numerous wide dark lines which are characteristic of the *Orion* type stars, and the bright borders of the hydrogen and helium lines which are characteristic of the bright-line stars of Classes B to A. These features aid in establishing the connection of the Wolf-Rayet with the early type stars, a connection quite certain but not fully understood.

G. F. PADDOCK.

September, 1914.

RELATION OF THE MOUNT WILSON PHOTOGRAPHIC AND PHOTOVISUAL MAGNITUDE SCALES.

With the aid of an objective-grating attached to the 60-inch reflector, HERTZSPRUNG has determined the effective wave-lengths of about two hundred stars in the cluster N. G. C. 1647. He has also provided data by means of which the color indices of the individual stars may be calculated from their respective effective wave-lengths.

Since color index is by definition the difference between photographic and visual (or photovisual) magnitude, it follows that a comparison of color indices derived from magnitudes with those calculated from effective wave-lengths affords a control upon the mutual relation of the photographic and visual magnitude scales. The test is the more important in that it can be applied to relatively faint stars. There is no particular difficulty in establishing the two scales so that, in accordance with international convention, they coincide at the sixth magnitude for stars of spectrum A0. But when this has been accomplished, it is difficult to find assurance that they stand in the proper relation to each other in the region of the fainter magnitudes. Any divergence, unless affecting both scales equally, must disturb this relation. As such divergences are notoriously difficult of detection, the suggested comparison of color indices seems important.

The test has been applied to the region investigated by HERTZSPRUNG by comparing the cluster with the Pole, for which both the photographic and photovisual magnitudes have been determined on an absolute scale. For the photographic scale ordinary plates were used; for the photovisual, isochromatic plates exposed behind a yellow filter, the instrument being the 60-inch reflector.

Inasmuch as any error in the zero point of the magnitudes for the cluster enters undiminished into the color indices, special precautions were taken. Only nights of first quality were used; observations were made, as nearly as possible, when the cluster was at the altitude of the Pole; the exposures were short, not exceeding five minutes; the multiple exposures always began and ended with the same field, so that the order was: cluster, Pole, Pole, cluster, or the inverse; and, finally, the number of comparisons was five for each scale, made upon five separate nights.

Each plate gave a series of magnitudes, photographic or photovisual, for the stars of the cluster based upon the Mount Wilson magnitudes for the polar stars. The means for the five series for each scale were adopted for the calculation of the color indices. The zero point deviations of the separate plates from the means for the five are:—

Photographic	+0.04	—0.04	—0.14	+0.14	—0.04	magnitude
Photovisual	+0.06	+0.01	—0.09	+0.03	—0.08	"

The indicated probable error in the zero points of the two scales is therefore ± 0.03 magnitude, so that the uncertainty in the color indices arising from this source is ± 0.04 magnitude.

Aside from this error, there is also to be considered that due to differences in slope between the adopted scale for the cluster and those of the Pole. The latter is, however, very small, as experience shows that the mean of five such comparisons reproduces the original scale with a high degree of precision.

We may consider, therefore, that the polar scales have been transferred to the cluster with negligible errors in slope and with uncertainties in the zero points of the order of 0.03 magnitude.

For the comparison with HERTZSPRUNG'S results only stars within the magnitude interval 11 to 14 were used. The magnitudes for objects brighter than 11, and the effective wave-lengths for those fainter than 14, are of low weight and unreliable. This restriction, and the limitation of the field, leaves available for the comparison 52 stars.

The color indices derived from the magnitudes show the same systematic change in the minimum index with increasing magnitude that was found by HERTZSPRUNG to characterize the effective wave-lengths—that is, the whitest objects among the faint stars are relatively red. The rate of increase in the color is slightly different in the two cases, but systematic differences between such different methods of measuring the effect are to be anticipated. This fact cannot, however, influence in any sensible degree the main result, which is as follows:

Mean C. I. 52 stars, magnitudes 11-14
From Mount Wilson magnitudes = −0.45 magnitude.
From HERTZSPRUNG'S effective wave-lengths = −0.48 magnitude

It is to be remarked that the zero points of the Mount Wilson scales for the polar stars are still subject to corrections of a few hundredths of a magnitude. It is unlikely, however, that all sources of error combined render the mean color index from the magnitudes uncertain by as much as a tenth of a magnitude.

The inference, therefore, is that for a mean magnitude which may be taken as 12.5, the Mount Wilson photographic and photovisual magnitudes are in substantially the correct relation to each other. From this it follows that if either scale deviates appreciably from the true absolute scale, the other must be affected by a similar divergence.

F. H. SEARES.

MT. WILSON SOLAR OBSERVATORY, August 18, 1914.

TWO NEBULÆ WITH LARGE RADIAL VELOCITIES.

In the course of the determination of the radial velocities of a number of nebulæ at Mount Hamilton, two planetaries in addition to those announced in Number 151 of these *Publications* have been found to have large velocities in the line of sight. They are: N. G. C. 6644 ($\alpha = 18^h\ 26^m.4$; $\delta = -25°\ 12'$), for which the mean of the measures of four spectrograms by Miss HOBE, Messrs. SELGA, S.J., and MOORE gives $+ 190.9^{km}$ and Second Index N. G. C. 4732 ($\alpha = 18^h\ 27^m.9$; $\delta = -22°\ 43'$), for which the mean of four spectrograms measured by the above observers is -147.7^{km}. The radial velocity corrected for the solar motion is therefore for the first nebula $+ 202^{km}$, and for the second $- 136^{km}$ per second.

J. H. MOORE.

PERSONAL NOTE.

The degree of Doctor of Philosophy in Astronomy, Mathematics and Physics was conferred on Mr. DANIEL WALTER MOREHOUSE, B. S., Drake University, 1900 and M. S., Drake University, 1902, at the annual commencement of the University of California on May 13, 1914.

Mr. MOREHOUSE holds the chair of physics and astronomy in Drake University. He has pursued graduate work in the Universities of Chicago and California, including theoretical work at Chicago and Berkeley and practical work at the Yerkes and Lick Observatories. He completed his studies for the degree in the University of California during the academic year 1911-12, while on leave of absence from Drake University and was awarded his degree upon submitting a thesis on the "Orbit of the Seventh Satellite of *Jupiter*," of which the following is an abstract:—

The original determination of the elements of the orbit of the seventh satellite of *Jupiter* presented an unusually difficult problem—designated almost impossible by some investigators—on account of the large and irregular solar perturbations during the time from January 3 to March 6, 1905, over which the discovery observations extended. Solutions, which took account of the perturbations, were accomplished by Dr. F. E. Ross by a general satellite theory and by Dr. R. T. CRAWFORD and Mr. A. J. CHAMPREUX by LEUSCHNER'S method of direct solution of orbits of disturbed bodies.

Both solutions require improvement, the former, although later extended by Ross to represent 12 observations distributed uniformly from January 3, 1905, to September 25, 1906, because the satellite theory was based on approximate osculating elements and confined to the principal terms; the latter because of the shortness of the arc from which the preliminary osculating elements were deduced.

The author undertook the task of deriving an accurate set of osculating elements by a further application of LEUSCHNER's method, partly for the purpose of testing the advantages of certain closed expressions, partly in order to test the accuracy of certain directions for taking full account of the aberration, and, finally, in order to provide a set of osculating elements of sufficient accuracy to serve as the basis of any future rigid satellite theory.

The plan of work involved an extension of the special perturbations and differential corrections on the basis of increased arcs of the preliminary elements computed by CRAWFORD and CHAMPREUX; the revision of the perturbations from the date of discovery at the original eight-day intervals on the basis of the corrected elements, and ultimately with even shorter intervals; and a repeated representation of the available positions for the purpose of eliminating defective observational material.

The investigation is not concluded, but the first two objects: the proof of the advantages of LEUSCHNER's closed expressions for correcting satellite orbits and of the accuracy of the directions for taking full account of the aberration, have been attained, while another revision of the special perturbations with a subsequent differential correction of the elements should give an orbit representing the available positions within the errors of observation.

A. O. LEUSCHNER.

VOLUME XI, PUBLICATIONS OF THE LICK OBSERVATORY.

This volume, entitled "Photographs of the Milky Way and of Comets, made with the Six-Inch Lens and Crocker Telescope during the Years 1892 to 1895 by E. E. BARNARD," has just been distributed to the correspondents of the Lick Observatory in the United States, Canada and Mexico. The distribution to European and other foreign correspondents is delayed by the war. The volume contains reproductions, by the collotype process, of eighty-eight photographs of the Milky Way, and thirty-nine photographs of comets; also a plate of lunar photographs, one of the solar corona of January 1, 1889, and one showing the Crocker dome and the Crocker telescope with the Willard lens. In addition to the descriptions of the individual plates, Professor BARNARD's introduction gives a general account of his pioneer work in astronomical photography.

PERSONAL NOTES.

Director CAMPBELL cabled to the observatory from London on September 8th that all the members of the eclipse party were in good health. The censorship of cable messages, it is presumed, prevented the sending of any further news as to the success of the observations at Kiev. On the same day a letter came from the eclipse station, mailed by a friend in England, and dated August 15th. At that date the preparations were complete for the observations of the 21st. The party expected to travel via Moscow and St. Petersburg, thru Finland and Sweden, to England; and this plan was probably carried out. The preparations for the war in Russia would probably not interfere with the work of the eclipse party, but they will have to leave their instruments and apparatus in storage, either at Kiev or possibly at Poulkova. Lacking further news, the party is expected to sail from England, as originally planned, on September 22d, and would be due at the observatory about the middle of October.

The news of the failure of the eclipse observations at Kiev, Russia, only reached the Lick Observatory on September 23d. The afternoon was cloudy, and the eclipse was not visible. Evidently a cable sent from the eclipse station on August 21st failed to reach its destination, which contingency was to be anticipated in the troubled condition of affairs in Europe.

Mr. SETH B. NICHOLSON, Instructor in Astronomy in the Berkeley Astronomical Department, University of California, completed his volunteer work at the Lick Observatory on August 3d. During the photographic exposures on the eighth satellite of *Jupiter* with the Crossley reflector, he noted a suspicious object in this region, fainter than any of the satellites hitherto photographed. The object was first identified on the plate of July 21st, and was photographed upon several plates of later dates. Mr. NICHOLSON returned to the Lick Observatory on August 21st, and made several exposures for further positions. His orbit computations have finally confirmed the first indications, given by positions and motions, and the object proves to be a ninth satellite of *Jupiter*. This information was telegraphed to the astronomical world on September 11th. Some of the faint stars, required for the determination of the positions of the new satellite, have been observed with the meridian circle by Acting Director TUCKER.

Miss CARRIE E. CASTLE assumed the duties of secretary of the Lick Observatory on July 7th.

Dr. W. W. COBLENTZ, member of the staff of the Bureau of Standards, Washington, D. C., completed his tests of the thermopiles of his own design, with the Crossley reflector, in August, and left the observatory on September 3d, to resume his work in Washington. In the six weeks spent on the mountain he was able to obtain satisfactory results, both qualitative and quantitative, of the heat of the various classes of stars of different magnitudes. The indications were registered by a most delicate galvanometer, and his entire apparatus is an example of the most advanced types of instrumental construction for investigations in physics, and its allied science, astronomy. He hopes to make further tests with even larger instruments than the Crossley reflector, at some favorable opportunity.

Dr. S. D. TOWNLEY, of Stanford University, has continued his variable star observations with a photometer attached to the 12-inch telescope of the Lick Observatory, during a part of the summer.

Mr. WARREN KIMBALL GREEN, A. B., Harvard University, 1913, began his graduate work as Fellow at the Lick Observatory on July 8th.

Dr. ELI STUART HAYNES, after spending an extra month at the Lick Observatory, left on August 3d to take up his duties at Beloit College.

Father M. SELGA, S. J., of the staff of the Manila Observatory, arrived at Mount Hamilton for volunteer work at the Lick Observatory on August 24th. Father SELGA has spent the past year in American observatories at Harvard, Georgetown and Flagstaff, and will continue his work here during the autumn.

In the latter part of July, while on Mount Wilson, Professor HALE suffered a sudden attack of appendicitis, which necessitated an operation. This was performed with entire success on August 8th. The recovery was rapid, and Professor HALE was able to leave the hospital for his home on September 8th.

GENERAL NOTES.

[illegible] the eclipse parties from the Royal Observa[illegible] headed by Messrs. Jones and Davidson, [illegible] excellent weather [illegible] on August 21st, [illegible] at Minsk, Russia. It is stated that the [illegible] type [illegible] Many [illegible] were [illegible]

[illegible] Father Cortie, S. J., [illegible] the [illegible] of the [illegible] Royal [illegible] Society [illegible] Sweden.

[illegible] of the [illegible] Society [illegible] held at [illegible] It was [illegible]

[illegible]

[illegible]

Preliminary investigation to determine the localities in Canada where the atmospheric conditions would be most suitable for the use of a large reflecting telescope was carried out by Mr. W. E. HARPER of the Dominion Observatory. From his report it appeared that if the telescope were not to be kept at Ottawa, Victoria was the only station that need be seriously considered. The superiority of this station over Ottawa in respect to "seeing" (3.8 to 2.6 on a scale of 5) and low range of night temperature (3°.8 C. as compared to 7°.6 C) decided the question.

It is stated in *Science* that the Nantucket Maria Mitchell Association is soliciting funds to endow an astronomical fellowship at the Harvard College Observatory. Upwards of $1,500 have been subscribed towards the $12,000 desired.

We record with great regret the death of three well-known European astronomers: CARL FREDERICK PECHÜLE, "Observator," of the University Observatory at Copenhagen since 1888, who died on May 28, 1914, at the age of 71 years; RUDOLF LEHMANN FILHÉS, "Honorar-professor" at the University of Berlin, who died on May 30, 1914, at the age of 60 years; and HERMANN J. KLEIN, of Köln-Lindenthal, editor of the popular astronomical journal *Sirius*, whose recent death, at the age of 72, is recorded in *Science*.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC HELD IN HEARST HALL, BERKELEY, ON JULY 11, 1914, AT 8:00 P. M.

By courtesy of the President of the University of California, and under arrangements perfected with Professor **CHARLES H. RIEBER**, Dean of the Summer Session of the university, a joint meeting of the Astronomical Society of the Pacific was held in Hearst Hall, Berkeley, on Saturday, July 11, 1914, at 8:00 P. M.

Professor R. T. **CRAWFORD**, of the Students' Observatory, delivered an illustrated lecture on the subject of "European Observatories" (second series). A large number of very interesting pictures was thrown on the screen, showing the positions, environment and equipment of many of the European observatories. The location of many of them, in the centers of large cities, was described as being unfavorable to seeing conditions and much inferior, in this respect, to American observatories. Notwithstanding their generally poorer location and equipment, Professor **CRAWFORD** described them as places of great charm and historical interest, more particularly because of their association with the names of men who have become immortal thru their work in astronomical science.

MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN HEARST HALL, BERKELEY, ON JULY 11, 1914, AT 7:15 P. M.

The minutes of the previous meeting were approved as printed.

The attention of the Board was directed by President **CRAWFORD** to the movement which has been set on foot, within the past few months, to merge the Pacific Association of Scientific Societies (of which the Astronomical Society of the Pacific is a constituent member) into a Pacific Division of the American Association for the Advancement of Science. The following communication from Professor J. N. **BOWMAN**, secretary of the Pacific Association, was read:—

PACIFIC ASSOCIATION OF SCIENTIFIC SOCIETIES

SEATTLE, May 26th, 1914.

MR. D. S. RICHARDSON,
Secretary Astronomical Society of the Pacific.

My Dear Mr. Richardson:

I enclose herewith a constitution for the proposed merging with the American Association into a Pacific Division. I commend it to your society for its action. The note will, I hope, explain still further. Any questions that may come to mind put to Prof. **TOWNLEY**, who was on the constitutional committee and who was present at the executive committee last Saturday.

Biology, Palæontology, Geology and Seismology have already accepted the constitution and are ready to sign it when presented.

Believe me very

Cordially,
J. N. BOWMAN.

NOTE.

At the executive committee meeting, May 23rd, 1914, the enclosed constitution was presented by Professor LOUDERBACK for his committee, appointed April, 1913. It was discussed at length, and regarding it the following motions were passed:—

It was moved by Dr. BRANNER, seconded by Prof. MERRIAM, that the committee's work be accepted, and that the constitution be approved and recommended to the constituent societies for their action. Carried unanimously.

It was moved by Prof. LAWSON, seconded by Prof. MERRIAM, that the Pacific Association shall cease to exist and become the Pacific Division of the American Association for the Advancement of Science at the close of the meeting of the American Association at San Francisco, August, 1915; provided, first, that by that time two-thirds of the constituent societies shall have approved the constitution—and signed it; and, second, that the officers of the Pacific Division shall have been appointed, organized and are prepared to carry on the work of the Pacific Association. Carried unanimously.

It was also carried unanimously (moved by Prof. LAWSON, seconded by Prof. MERRIAM) that the secretary be instructed to send a copy of the constitution to the secretary of each constituent society, who has not already received a copy, with the request that each society act on the question of adoption or rejection of the constitution at its earliest convenience and report to the secretary of the Pacific Association its action.

It was carried unanimously that it be the understanding that the current expenses of the secretary until the transfer of the Pacific Division be paid by the Pacific Division of the American Association. J. N. BOWMAN.

After some discussion, and on motion of Director AITKEN, seconded by Director CORNISH, the Board voted to act in harmony with the plan of the Seattle meeting and to acquiesce in the merging of the Pacific Association into a Pacific Division of the American Association for the Advancement of Science. The President and Secretary were, therefore, instructed to sign the proposed constitution of the new organization and return it to Secretary BOWMAN with the approval of this society.

The Secretary-Treasurer reported to the Board the failure of the Contra Costa Water Company to pay the July, 1914, interest upon the three bonds of that company held by this society. The matter was referred to the Finance Committee, with authority to take such steps as might be necessary to protect the interests of the society.

A verbal report was made by the Secretary (who had been appointed a committee of one for that purpose at the last meeting) to the effect that no obstacle existed in the postal laws to prevent the insertion of advertisements in our *Publications.*

A propos of the last award of the Bruce Medal to Dr. BACKLUND, of Pulkovo, the following letter from the recipient was read by the Secretary:—

OBSERVATOIRE CENTRAL NICOLAS.
POULKOVO PRÈS DE ST. PÉTERSBOURG.
CABINET DU DIRECTEUR.

May 24, 1914.

THE SECRETARY OF ASTRONOMICAL SOCIETY OF THE PACIFIC,
D. S. RICHARDSON.

Dear Sir:

Expressing my sincere thanks for your amiable letter of April 6, I have the honor to report that the Chargé d'Affairs of the American Embassy at St. Petersburg has delivered to me the Bruce Gold Medal. My absence abroad for some weeks delayed the reception.

I beg you to be so good as to transfer my thanks to the society and tell the members that I regard this distinction as the highest an astronomer can receive and that I fear it is above my merits. You may be convinced of the sincerity of this feeling, when I tell you that I admire the American astronomers on behalf of their energy, their methods, their keen scientific ideas and the mighty progress of astronomy which we are indebted to them.

Yours, very gratefully,
O. BACKLUND.

Adjourned.

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Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

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The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

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Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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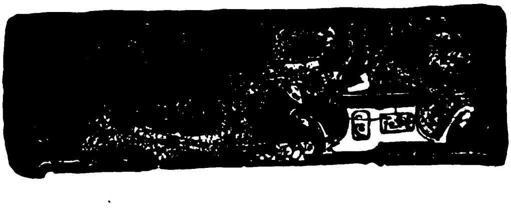

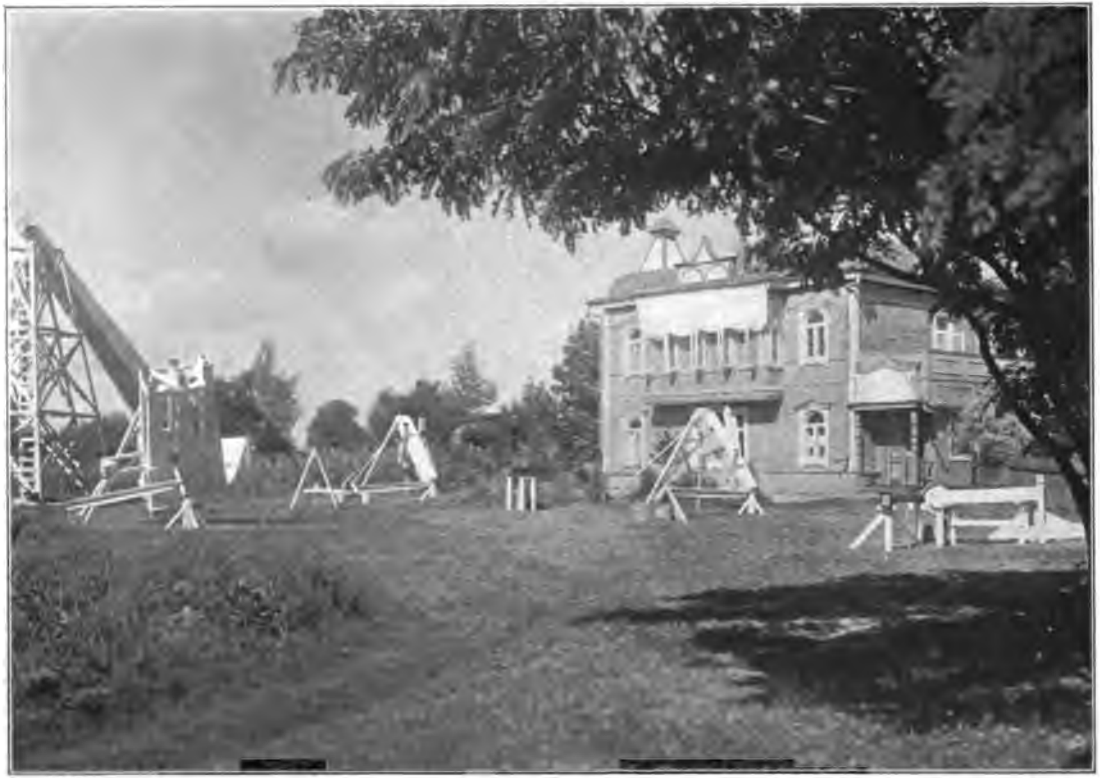

General View of Eclipse Camp at Datcha Lavrovskavo, Brovarý, Russia.

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THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION TO BROVARÝ, RUSSIA.

BY W. W. CAMPBELL AND HEBER D. CURTIS.

Tho this powerfully equipped eclipse expedition shared the ill-fortune of several other large eclipse parties in Russia in its failure to secure any results because of unfavorable weather conditions, a description of the camp, the equipment, and the proposed observations may not be without interest, and it should be a matter of record.

It is superfluous to express our gratitude to Regent WILLIAM H. CROCKER for the gift which made the expedition possible. Thru the gifts of Mr. CROCKER especially, his brother, and of Mrs. PHŒBE A. HEARST, the Lick Observatory has been enabled to send well-equipped expeditions to observe all the more important total solar eclipses since its completion in 1888, resulting in a collection of eclipse observations which is doubtless the most extensive in existence. For a number of eclipses in this interval of twenty-six years no attempt was made by the Lick Observatory to send expeditions because of known poor chances of success; and in nearly all these cases the lack of success by the astronomers who went has shown the wisdom of our abstention. That the present expedition cannot claim the success which seven out of our eight earlier expeditions experienced must be accepted as one of the "fortunes of war."

Accurate information bearing on the probable weather conditions at various possible sites along the path of totality was unusually difficult to secure. Published records seemed to leave no doubt that the probabilities of freedom from clouds were better the farther south one went, the cloudiness factor ranging from about 6.8 in Sweden and Riga to 2.3 in the Crimea, on a scale of 10 for total cloudiness. It was absolutely essential to be as near as possible to the central line for the observations to be made with the moving-plate spectrograph. The lowlands and other unfavorable conditions along the central line in the Crimea, and the advantages of nearness to a large city (other things being equal), finally led to the tentative selection of a site to be located as near as possible to the central line where this line passed thru the small town of Brovarý, some twelve miles northeast of Kiev, in the Government of Chernigov. Also, because of the fundamental requirement as to position on the central line, it was necessary to decline, with great regret, several very kind offers of sites. Mr. GREFS, Court Chamberlain to the Czar, with characteristically generous Russian hospitality, offered us a site on his country estate at Stavidly, a hundred miles, more or less, southeast of Kiev; the party of eight would be his personal guests, and he would supply all the labor and local transportation we needed. But the distance of Mr. GREFS's estate from the central line (13 kilometers) compelled us regretfully to decline this exceedingly generous invitation. That given after we reached Kiev by the Lord Mayor of Kiev to locate on his beautiful grounds, and Professor VOGEL's offer of a site in the large enclosure about the Kiev Observatory, were declined for the same reason.

In addition to the instruments, a full equipment of camp furnishings, supplies, and staple foods was taken, repeated experience having shown the great increase in comfort and efficiency to be gained by making a large eclipse camp an independent unit, with no need to rely upon local accommodations or sources of supply. The freight shipment, amounting to about four and a half tons, went by the steamer "Czar" of the Russian-American Line direct to Libau, Russia, which was reached on July 8th. It has been our invariable rule to have some member of the eclipse party accompany the freight shipment thruout its entire course; this has often saved serious delays and inconveniences. Mr. CURTIS accordingly accompanied the freight. It was planned for him to select a suitable site to the northeast of Kiev as close as possible to the central line, at which point Mr. CAMPBELL and the rest of the party would later join him, travelling via Italy and Austria.

The Russian Government had granted to foreign eclipse expeditions free entry for the instruments, provided none were left in Russia, free railway transportation of the instruments, and half-fare passenger tickets. The customs concession was interpreted rather strictly, so that more examination was deemed necessary by the officials at Libau than we had expected, but the officials showed the expedition every possible curtesy.

Mr. CURTIS reached Kiev on July 11th. The search for a suitable location proceeded rather slowly, as this was the summer vacation season, and nearly all officials or scientists who might be of service were away. However, invaluable assistance was rendered at this time and thruout our stay by several members of the Kiev Circle of Amateur Astronomers. To these gentlemen, in particular to Mr. NICOLAS ZENCHENKO, the able president of this society, and to Mr. IVAN ILIINSKY, a prominent member of the society, our heartiest thanks are due. During the days spent in the selection of the camp, thru the troubled and changed conditions brought on by the war, and until our final departure from Kiev, Mr. ZENCHENKO and Mr. ILIINSKY placed themselves unreservedly at our disposal, and were always ready to assist or advise. Our thanks are also due Mr. MEYER, for valuable assistance rendered at this time.

The site selected was the Datcha Lavrovskavo, a fine country estate belonging to Judge LAVROVSKOY, situated on the northern edge of the village of Brovarý, almost precisely on the central line, as corrected by the English astronomers on the basis of recent observations of the Moon's motion. The estate was unoccupied, as Judge LAVROVSKOY had been transferred to another district some time before, but by a very fortunate coincidence Madame LAVROVSKOY happened to be staying there for a few days, and arrangements for its rental were made at once. We are grateful for her curtesy in allowing us to occupy this fine site and for her assistance in arranging the first details of our occupancy. The Datcha comprised eleven acres, all enclosed, an excellent two-story residence, barns and out-buildings, cellar, conservatory, and even a small observation tower. A few hours' work converted the half-underground winter section of the conservatory into a very convenient dark room. There were many fruit trees, some larger timber, and a lawn in front of the house which offered an ideal site for the instruments.

Tents had been taken for the camp, and it had been planned to construct a kitchen tent, a large dining tent, and a dark room, but the fortunate location at the Datcha made all this unnecessary; a few tents were put up for the younger members of the party who preferred to sleep in true camp fashion, and for work tents. Brovarý is a typical Russian town of perhaps three thousand inhabitants, with unimproved dirt streets whose condition becomes indescribable after a heavy rain. A fine military road and a motor tram line connect it with Kiev. Kiev is a thoroly modern city of over half a million inhabitants, picturesquely located on high bluffs along the Dnieper River. The view of the gilded domes of its many churches and cathedrals, and the panorama of river and plain to be seen from the open-air restaurant of the Kupetchky Sobraniya (Merchants' Club) on a bluff overlooking the Dnieper, are very fine.

The freight was taken out to the camp on July 18th and unpacked; Mr. CAMPBELL and the other members of the party arrived on the 21st. The party numbered eight: Director CAMPBELL and Dr. CURTIS; Mrs. CAMPBELL and her mother, Mrs. ELIZABETH THOMPSON; and, in the capacity of voluntary assistants, Dr. CAMPBELL's three sons, WALLACE CAMPBELL (Harvard '16), DOUGLAS CAMPBELL (Harvard '17) and KENNETH CAMPBELL (Hotchkiss '17); and Mr. CHARLES F. BRUSH, JR., (Harvard '15). Within three days the living arrangements were perfected, and the real work of preparing for the eclipse was begun.

With the four energetic and active young Americans as helpers the work of setting up the instruments proceeded very rapidly; in fact, as time progressed, it became increasingly difficult to provide work for our insatiable young assistants. So rapidly did the work go that the last two weeks were easy, and everything could have been in readiness ten days before the eclipse. Mrs. CAMPBELL, as at several previous eclipses, was a most efficient "Secretary of the Interior," administering to our material wants with the assistance of a large domestic staff, and seeing to it that our drinking water was adequately boiled and sanitarily irreproachable. All in all, our life at the Datcha Lavrovskayo was a very pleasant one, and the members of the party will always remember it as a very delightful experience, except for the vital two minutes and fourteen seconds on the day of the eclipse.

The instruments were as follows:—

1. The 40-foot Telescope. This instrument, for large-scale photographs of the corona, was mounted as in previous eclipses, and no further description is necessary. With this instrument ten exposures varying from instantaneous to 32 seconds were to be made on 14 × 17-inch plates. It was in charge of Mr. WALLACE CAMPBELL, assisted by Mr. GEORGE M. DAY. Mr. DAY and his family are the only Americans in Kiev, to the best of his knowledge; he is in charge of the International Y. M. C. A. work in Russia, and we take this opportunity to thank him for the many important ways in which he assisted us.

2. The Polarizing Photometers. These instruments were the same as those used in the eclipses of 1905 and 1908, with the exception that light tubes and diaphrams were provided in front of the objective ends so as to prevent the entrance of light from any other region than that immediately about the Sun. Two of these photometers reflected the light from the corona into the cameras by means of unsilvered glass flats placed at the polarizing angle, and the photometers were mounted at 90° to each other. A third camera was pointed directly to the corona, the aperture of the lens being stopped down to 0.62 inches. The apertures of the others are two inches each, and the focal lengths of all three are very close to fifty inches. These polarigraphs, and the one-prism spectrograph described in the next paragraph, were mounted on the northern polar axis. This axis and its instruments were in charge of Mr. DOUGLAS CAMPBELL, assisted by Mrs. CAMPBELL, Mr. ZENCHENKO, and Mr. MERELLI.

3. The One-Prism Spectrograph. Image lens 1.62 inches aperture and 12.75 inches focal length; collimator lens two inches aperture and 32 inches focus; camera lens 2.06 inches aperture

and 12.40 inches focus; and a 60° prism set for minimum deviation at Hγ. Purpose, the photography of the coronal spectrum, and a study of the light distribution in the coronal spectrum.

4. Three-Prism Spectrograph for accurate determination of wave-length of the green coronal line. Three very dense flint 60° prisms; image lens 2.12 inches aperture and 20.2 inches focus; collimator lens 2.5 inches aperture and 20.96 inches focus; camera lens 2.06 inches aperture and 17.92 inches focus; curved slit with radius of 3.3 inches; total deviation 169° 39′.

5. Objective Grating Spectrograph for study of distribution of the gas in the inner corona which forms the green ring in the spectrum of the corona. Michelson plane grating 15,000 lines to the inch, ruled surface 2.68 by 3.86 inches, used in the second order: a triple camera lens 3.25 inches aperture and 24 inches focus, corrected for the D region of spectrum.

6. Ultra Violet Objective Spectrograph. Single U. V. glass prism, 60°; triple U. V. glass lens 2.60 inches aperture and 78.74 inches focus; corrected for wave length 3500. Purpose, to record violet and ultra violet coronal spectrum, and the photometry of the spectrum. The three spectrographs last mentioned were mounted on the southern polar axis, and were in charge of Mr. CHARLES F. BRUSH, JR.

7. Moving Plate Spectrograph for "flash" spectrum. Two 60° prisms giving a deviation at Hγ of 100° 8′; triple camera lens, corrected for Hγ, 2.12 inches aperture and 60 inches focus. The plate-holder movement was controlled by a valve regulator on a glycerine clepsydra cylinder, as used in the eclipses of 1905 and 1908. The exposure at this instrument was by Mr. CAMPBELL; it was mounted nearly horizontally in such a position that the tangents to the cusps at second and third contacts would be parallel to the refracting edge of the prisms, and it received its light from a coelostat.

8. The Floyd Telescope, five inches aperture and 70 inches focal length, for smaller-scale photographs of the corona, was mounted horizontally, receiving its light from the same coelostat as the moving-plate spectrograph. The exposures at this instrument were in charge of Mr. LINNIK.

9. Four Cameras with lenses of three inches aperture and 11 feet 4 inches focal length. These lenses, and the sheet steel tubes in which they were mounted, had been used in previous eclipses in the search for intramercurial planets. While it was the intention to search for such objects on the plates taken with these instruments, this was secondary to the main purpose. It is an interesting consequence of the theory of relativity that a beam of light passing thru a gravitational field should suffer a minute deflection; the total amount of this deflection for a ray from a star passing close to the limb of the Sun would be $0''.83$ of arc. The doubled effect, for a pair of stars situated on opposite sides of the Sun and 20′ distant from the limb, would amount to three-quarters of a second of arc.[1] At present this seems to be about the only physical observation which we can make to test the theory of relativity, and naturally it can be made only at the time of total solar eclipse. Professor EINSTEIN, the chief developer of the theory of relativity, has been quite anxious that eclipse observations be made to decide the question of the existence or non-existence of such a deflection of light when passing thru a strong gravitational field. While a deflection of the rays from nearby stars, if found, might be complicated with questions as to the amount of refraction caused by the rare matter of the corona, the problem seemed to be of sufficient importance to warrant a thoro trial. The tubes were so arranged that the Sun's image fell in the center of each of the four 16 × 20-inch plates used. The axis on which these tubes were mounted was rated for sidereal instead of solar time. Comparison plates of the eclipse region of sky were taken at Mount Hamilton with the instrument set up exactly as it was to be used at the eclipse, and with exposures of the same length as that to be obtained at the eclipse. By measuring the stars found near the Sun on the eclipse plates, and comparing their positions with the positions given for the same stars on the comparison plates, any changes due to the action of the Sun in bending the rays of light passing near it, could, it is believed, be detected.

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[1] Cf. articles in the *Publications of the Astronomical Society of the Pacific* **[illegible]**, 219, 272, and **[illegible]**, 77.

As *Regulus* was very favorably placed, slightly over a degree from the eclipsed Sun, a fifth lens of the same size and focal length was mounted with the other four, having an ocular provided with cross-wires, and set by calculation so as to have *Regulus* central when the Sun's image was central on the large plate; it was hoped to be able to use *Regulus* in this way as a guiding star, to insure perfect roundness in the star images. This mounting was in charge of Mr. CURTIS, who was assisted by Mr. MORGILEVSKY and Mr. ILIINSKY.

10. Extra-focal Photometers. These were mounted on the same axis as the four lenses for the relativity test, and consisted of two other lenses of the "Vulcan" type mounted seven inches apart in the end of a double camera tube. The images of the Sun formed by both these lenses fell upon the same 14 × 17-inch plate at the lower end. The lenses (of three inches aperture and eleven feet four inches focal length), were mounted three inches out of focus, and one of the pair was stopped down so as to give a light reduction of one magnitude. By means of standard squares on the plate and the extra-focal images of the corona and of *Regulus* it was hoped to secure photometric results of considerable value, and data as to the density of the matter forming the corona.

11. A Chronograph was mounted and connected with the observing chamber of the 40-foot telescope for recording the times of second and third contacts; it was also connected with automatic contacts on the exposing shutter of the moving-plate spectrograph to record the exposure times with that instrument.

The signals at predetermined intervals before totality. and the counting of the seconds for the observers were given by KENNETH CAMPBELL. General NICOLSKOY and his son, with a small telescope for visual observations of the corona and prominences, were also at the camp on eclipse day.

All the plates of the various photometric programs, and selected plates of the 40-foot and Floyd programs, were standardized by the imprinting of photographic squares from an amyl-acetate lamp, the principle of equal exposures in equal times at varying distances being followed as far as possible, instead of varying exposures at a fixed distance.

Mr. WALLACE CAMPBELL had charge of the meteorological observations at the camp. The geographical co-ordinates of the camp at Datcha Lavrovskavo are as follows, determined by sextant observations for latitude and time and by transport of our chronometer to the Observatory of Kiev for longitude:—

Longitude, $2^h\ 3^m\ 5^s.5$ E. of Greenwich
Latitude, $+50°\ 30'\ 24''$

We are indebted to Professor VOGEL, Director of the Royal Observatory, Kiev, for the comparison of our chronometer time with accurate Kiev time.

We had not been very long in camp before it became evident that the chances for success on August 21st were very, very slight. To quote from Mr. WALLACE CAMPBELL's report on the weather conditions during our stay:—

"Of the thirty-five days during which the party was at the station, only ten could be called at all favorable for eclipse observations at 2.47 P. M. (the time of mid-totality), and the conditions on these days were not satisfactory. Not one day of the thirty-five was entirely clear at eclipse time. On average days if a storm was not in the neighborhood the conditions were these: cumulus clouds appeared in a clear sky about 10 A. M., and increased steadily to a maximum of about eight-tenths between 2 and 3 P. M. The cumulus then decreased, disappearing by sunset, and the nights were clear."

Observers at Minsk, Theodosia, and other places on the line of totality report precisely the same state of affairs, and examination of weather records for the past ten years shows that this is the rule in the summer weather of western Russia. That this fact, so salient and so vital from an eclipse standpoint, namely, that the maximum of day cloudiness came almost precisely at eclipse time, was not noted and communicated to intending observers, seems to have been an inexplicable omission. It is not too much to say that the Lick Expedition would not have been sent had this important fact been known in advance.

Stormy conditions prevailed on the 19th and 20th, and the "tail" of this storm, which so fortunately left clear weather in Sweden and Riga, was just passing at eclipse time on the 21st.

Nothing could be seen of the eclipsed Sun, and no observations of any sort could be made. Ten minutes later a little might have been secured thru a cloud gap, and one hour later the region about the Sun was beautifully clear. The temperature fell irregularly for fifteen minutes after the first contact, then uniformly until twelve minutes after the end of totality. The total fall was 2°.6 C. The rate of fall was not noticeably increased during totality. The eclipse was a very dark one for us, probably owing to the thick clouds. Messrs. JONES and DAVIDSON, at Minsk, secured excellent results thru a clear space in the generally clouded sky; in the Crimea, Dr. PERRINE and Professor NEWALL were unfortunate enuf to strike a cloud between two clear spaces, and secured no results. Several small parties in the Crimea, however, located but a short distance away, had spaces of clear sky about the sun at eclipse time and were successful.

Some ten days after starting life in camp came the order for the Russian mobilization, and we shall always remember the long sad procession of rude carts which passed the Datcha early one morning, transporting the men of our little town to their mobilization depot. The priests, carrying the glittering icons and banners, gave them their blessing, and the scenes of parting with the wives and children were heart-rending; it was already a tragedy to these peasant women, left behind to gather in their little crops for the winter, and we could but recall that this same tragedy was doubtless at that time being multiplied ten thousand fold by similar scenes in nearly every square mile of Europe. Then came in quick succession those declarations of war which have embroiled Europe in a catastrophe such that the wildest writer of fiction could not have predicted or imagined six months ago. Tho Kiev is one of the main mobilization centers, the existence of a state of war did not materially change life in the city, and in our quiet Datcha we experienced only a few minor annoyances, but no serious difficulties. We were impressed with the thoro and business-like character of such portions as we saw of the Russian mobilization; when we left, one month after the declaration of war by Germany, there were still forty great troop trains a day passing thru Brovarý, and earlier in the mobilization there were more. Communication between Brovarý and Kiev became more difficult and uncertain. All gasoline was commandeered, and the never-too-reliable tram was forced to use kerosene instead, while the great Alexander Chain Bridge over the Dnieper was frequently closed for hours at a time for the passage of troops or interminable batteries of heavy artillery. We had intended to bring our Russian volunteer assistants from Kiev to the camp by automobile for the preliminary drills, but all automobiles were taken for military purposes, and according to military proclamation no civilian could even ride in an auto on the streets of Kiev without a permit from the commandant. "International complications" arose over our jewel of a cook; born in Berlin, she had been so long in Russia that her German speech was not above reproach; able to read and write neither Russian nor German, she did not seem at all dangerous, but no exception could be made to the general order which placed under supervision or detention all German or Austrian subjects. The arrest of this energetic character left such a gap in the internal economy of the camp, that all our influence and that of our Russian friends was at once exerted, with the result that after four days she was brought back rejoicing to a welcoming camp. We were treated with great consideration by the officials, and we realized that the small annoyances and troubles we occasionally experienced were due solely to war conditions, and would never have been met with under ordinary circumstances. The German expeditions at Theodosia were not permitted to set up their instruments; the older members of the parties were ordered to leave at once; Doctors FREUNDLICH and ZURHELLEN of the Berlin Observatory and their mechanician MÉCHAU, being reservists in the German army, were detained, and are believed to be at present in the Volga district as prisoners of war.

There seemed to be no cause for anxiety as to any hostile action on the part of the simple, kindly Russian peasants, but, that there might be no reason why these should in ignorance be inclined to connect three such events as the eclipse, the American party and the war, brief and sensible proclamations were published by the Governors of Kiev and Chernigov, and by the Metropolitan of the Greek Church in Kiev, explaining the phenomenon. The *ispravnik,* a high official of our district, thought he would do the same, and his proclamation is one of our cherished mementoes of the trip; he advised that the children should be kept indoors and the cattle not be sent out to the fields on the day of the eclipse!

As no civilian freight was being carried by the railroads, the disposal of our instruments became a problem, but this was solved thru the kind assistance of General NICOLSKOY, who secured special railway transportation from Kiev to the Russian National Observatory at Poulkowa, where Director BACKLUND is kindly storing the instruments. Whether they are still in storage there, or are being sent to us via Vladivostock and the Pacific, we do not know.

For two weeks before we left the observing station we gave considerable thot to the problem which was always referred to as "getting out." The party had railway tickets, purchased before leaving America, reading thru Berlin and Paris, to London, but manifestly no longer of value. The route via Odessa and Constantinople was impossible, as the Russians daily anticipated that Turkey would declare war. A direct rail journey from Kiev to Petrograd, under the war conditions, was very uncertain, and the route via Moscow, Petrograd, and Finland was the only practicable one save that via Siberia. It was feared that the trip would be a long, and perhaps a very trying one. Only one passenger train a day ran from Kiev to Moscow, and neither money nor influence could guarantee a seat on this long, slow and crowded train. As it turned out, this portion of the journey homeward was the only really unpleasant part; from Moscow on, while there was always uncertainty, good accommodations were available. From Moscow we went to Petrograd. Two days were spent there, as the movement of troops in Finland and the taking off of certain trains made it impossible to leave more quickly. It seemed advisable to get to London at the earliest possible moment, partly because of rumors that nearly all Atlantic passenger steamers had been taken off for troop-transport service, but principally because on each section of the journey (except in Sweden and Norway) it was impossible to get reliable information concerning available travel facilities on the next section. It was important to "keep coming." Aside from cloudy sky on August 21st, our great disappointments were that we could not take time to visit the Poulkowa Observatory, nor to see our good friends in Stockholm. Professor and Mrs. BACKLUND and Professor BELOPOLSKY kindly came to Petrograd to see us and assist us. We take pleasure in acknowledging a great many acts of kindness and assistance to the expedition by Professor BACKLUND, and also the favors extended us by the Russian Imperial Academy of Sciences.

At Petrograd we were joined for the trip "out" by Messrs. PERRINE and MULVEY of Córdoba, who had been at Theodosia, and Messrs. JONES and DAVIDSON of Greenwich, who had been at Minsk. Passing through Finland, we stopped half a day at Tammerfors, a wonderfully clean Finnish manufacturing center; from here we went to Raumo, Finland, where steamer was taken for Stockholm. Twice on this trip passengers were ordered below decks while the steamer threaded passages on the Swedish coast. The youngest member of the party, with American longing for excitement, frequently expressed the hope that we might see a German cruiser, a wish which was not at all echoed by our English colleagues.

After a pleasant day at Christiania, the party went on to Bergen, thence by steamer to Newcastle, England. The lifeboats were in unostentatious readiness on this trip, but no mine was met with, and the party were very glad to step upon English soil, where everything seemed outwardly to be perfectly normal and going on as usual. Mr. BRUSH, by a quick trip across England, just managed to catch the steamer on which he had engaged passage. DOUGLAS and KENNETH CAMPBELL, unable to reach Rotterdam for their steamer, had a novel experience of traveling home by steerage. The rest of the party, unable to secure any earlier steamer accommodations than those they had engaged in March, spent two very enjoyable weeks in London, and reached Boston on the 30th of September, glad to be once again in a land where, to quote one of our number, "we are citizens and not subjects."

PLANETARY PHENOMENA FOR JANUARY AND FEBRUARY, 1915.

By Malcolm McNeill.

PHASES OF THE MOON, PACIFIC TIME.

Full Moon......	Jan. 1,	$4^h\ 21^m$	A.M.	Last Quarter...	Feb. 6,	$9^h\ 11^m$	P.M.
Last Quarter...	" 8,	1 13	P.M.	New Moon	" 13,	8 31	P.M.
New Moon	" 15,	6 42	A.M.	First Quarter...	" 21,	6 58	P.M.
First Quarter...	" 22,	9 32	P.M.				
Full Moon	" 30,	8 41	P.M.				

There will be only two eclipses during 1915, both of them central eclipses of the Sun. This is not a very common occurrence, but it happened in 1904. The usual number is four or five. The first of these will not be visible in America, as it will occur on the night of February 13th-14th, P. S. T. As the Moon is in that part of its orbit which is farther than its average distance from the Earth, its apparent size is less than that of the Sun, and the eclipse will be annular, not total. The path of the annulus runs from a point south of Madagascar to the central Pacific, the only large bodies of land encountered being Australia and New Guinea. The second eclipse comes in August and will be referred to in a later paper.

The Earth passes perihelion on the morning of January 2d.

All of the planets except *Saturn* and *Neptune* are in the same quarter of the sky as the Sun, some as morning and some as evening stars.

Mercury is a morning star on January 1st, but too near the Sun for naked-eye observation. It passes superior conjunction on the morning of January 5th and becomes an evening star, retaining this condition until February 21st, then passing inferior conjunction and becoming a morning star again. It reaches its maximum apparent distance from the Sun, 18° 14′, on the afternoon of February 5th, and then remains above the horizon about an hour and a half after sunset. For ten days before this date and a week or so after it will be in fair position for evening observation. As the planet passes perihelion only two days after the time of greatest elongation, its apparent distance from the Sun is nearly the minimum for a greatest elongation, and the length of the period of visibility is smaller than usual. The next period of visibility as an evening star will occur in May and June, and will give a longer and better opportunity for naked-eye view. *Mercury* will be in conjunction with *Mars* on January 1st and February 28th, with *Uranus* on January 20th, and with *Jupiter* on February 1st and February 18th. The planets are too near the Sun for naked-eye views of most of these, but that with *Jupiter* on February 1st can be easily seen if the weather is good. At the time of nearest approach *Mercury* will be 0° 33′ north of *Jupiter*, a trifle more than the Moon's apparent diameter. As seen in this country, however, the distance will be a little more, the time of conjunction not coming until after the planets are below our horizon.

Venus is now a morning star, having passed inferior conjunction with the Sun on November 27, 1914, and will remain a morning star until it reaches superior conjunction on August 14th. It is at its greatest brightness on January 2d, and for a few weeks it will be visible to the naked-eye in full daylight. It slowly increases its apparent distance from the Sun up to February 6th, when it reaches its greatest west elongation, 46° 54′. It passes perihelion on January 6th, but as the orbit is only slightly eccentric this makes little difference in its appearance, as compared to the effect produced under like circumstances on *Mercury* and *Mars*, whose orbits are very eccentric. Thruout January *Venus* will rise rather more than three hours before sunrise, but the interval will shorten up during February to less than two hours and a half.

Mars is a morning star on January 1st, having passed conjunction with the Sun on December 23, 1914, and will remain a morning star thruout the year and until it reaches opposition in February, 1916. On January 1st it rises only a few minutes before sunrise and the interval increases so slowly that it is only a little over half an hour by the end of February. This combined with its comparative faintness, due to the fact that it is on the opposite side of the Sun from us, will make naked-eye view practically impossible during this period.

Jupiter is an evening star on January 1st, setting about three and a half hours after sunset, and is in a fair position in the southwestern sky for early evening observation; but the interval diminishes to about one hour and a half by February 1st, and the planet comes to conjunction with the Sun on February 24th. There is a very close conjunction with the Moon, which becomes an occultation for some parts of the world, on the afternoon of January 17th, and another not quite as close on the afternoon of February 14th.

Saturn is in fine position for observation at almost any time of the night, having been in opposition with the Sun on December 21, 1914. By the end of February it sets at about 2:30 A. M. It is on the border-line between the constellation *Taurus* and *Gemini*, a few degrees south and east of *β Tauri*. Between January 1st and February 25th it moves about 3° westward, and then begins its eastward motion.

Uranus changes from an evening to a morning star on February 1st, when it passes conjunction, but it is too near the Sun for naked-eye view thruout the period.

Neptune comes to opposition with the Sun on January 19th. It is in the eastern part of the constellation *Cancer*.

PUBLICATIONS OF THE LICK OBSERVATORY, VOLUME XI: PHOTOGRAPHS OF THE MILKY WAY AND OF COMETS; BY E. E. BARNARD: A REVIEW.

By Joel H. Metcalf.

No publication of the Lick Observatory since Volume VIII, which contained reproductions of the photographs taken by Professor James Edward Keeler with the Crossley reflector has such general interest as Volume XI, which has just issued from the press. It contains reproductions of photographs of the Milky Way and of comets made with the 6-inch Willard lens and Crocker telescope during the years 1892 to 1895 by Professor E. E. Barnard at that time Astronomer in the Lick Observatory.

As the Crossley telescope is 36 inches in aperture, one might think that the next photographs reproduced would be those taken with some larger instrument, say of 60 or 100 inches aperture; but, instead, these photographs, which were the first of the kind and most wonderful in their results, were made with an instrument nominally only six inches in aperture and really smaller. Professor Barnard has been a daring and a most successful astronomical discoverer, but never did he show such radicalism as when he, one of the keenest sighted and most experienced of observers, spent night after night in photographing the sky with so small an instrument and one that was not even made for the stars. It was originally a portrait lens, of the form adapted to the old "wet-plate" process of photography, and long ago discarded by photographers as a result of the invention of the "dry-plate" and the anastigmatic lens. The volume under review is a proof that the old scriptural saying may have a modern application, for in it the lens that the builders rejected is head of the corner.

How the lens came to be used in astronomical work on Mount Hamilton is described by Professor Barnard in the introduction. The first experiments in astronomical work with an oldfashioned portrait lens of the Petzval type were made by Dr. DAVID GILL at the Cape of Good Hope on the great comet of 1882. In January, 1889, a 6-inch "Willard" lens was used by WM. IRELAND to photograph the total eclipse of the Sun, and its success then led to its purchase by Director HOLDEN for the Lick Observatory, the funds being provided by the Hon. C. F. CROCKER, Regent of the University of California. The information given shows that the lens was neither made by WILLARD nor is it six inches in aperture. WILLARD & Co., who have their name upon it were stock dealers only. The lens was made by CHARLES F. USNER in New York City. His name should not be forgotten, for it is doubtful if lens-makers of to-day can turn out an instrument greatly its superior.

It is true, however, that BRASHEAR has refigured it, which doubtless adds much to the sharpness of its images. The chief limitation of the original lens must have been the fact that the optical and visual foci coincided, as was necessary for focusing in the old wet-plate process. A modern instrument made exclusively for astronomical photography would have a better color correction and would give sharper images; otherwise it could not be greatly improved upon to-day. It is rather disconcerting that so little progress in the construction of astronomical lenses of large relative aperture has been made in the last fifty years. The only improvement, in the opinion of the writer, is the 10-inch Franklin-Adams lens made by TAYLOR of COOKE & Co., York, England, and it is practically impossible to get discs of the proper kind of glass for apertures larger than this.

Returning to the Willard lens, it is interesting to know that the clear diameter of the front lens is only 5.85 inches and that this is still farther cut down by a diaphram less than four inches in diameter, placed between the front lens and the back lens of the combination. But lenses, like wisdom, are justified of their children and Professor BARNARD has shown what this lens can do in skillful hands.

In the volume are 128 collotype plates, 89 of them of regions of the sky mostly along the Milky Way and the rest of comets. Professor BARNARD's decision to use the collotype process seems especially fortunate. The reproduction of star pictures to retain the fainter stars without loss of the fainter detail in the nebulæ is an art in itself, as difficult perhaps as making the original photographs. Mr. A. B. BRUNK of the Chicago Photogravure Company has succeeded admirably and must have put much patience and many labors of love into this work. Not all the reproductions are equally good, but when Professor BARNARD says, as he does often, "this is an excellent reproduction," there must have been very little in the original that does not show in the copy.

Professor BARNARD has given some very important technical hints in regard to the production of astronomical photographs in his Introduction. One might wish he had gone farther and told us about his enlargements of the original negatives—why he did not use contact reproductions and what was done to increase contrast in the tails of comets and the dark places and lanes in the Milky Way. In some of the pictures which have been several times enlarged the background shows a mottled appearance, doubtless due to the grain of the plate, but which some might take for a background of very faint stars.

Just a few words in regard to the plates themselves. The large number is food for thought for those who live in the cloudy atmosphere of the effete East. What a wonderful climate has Mount Hamilton to make it possible to get such a large number of long exposure plates in three or four years! For one who has ever tried to take a long-exposure plate there is a deep appreciation of the long and wearisome hours spent by Professor BARNARD, sitting with his eyes "glued" to the following telescope. Without counting the comet pictures and making no allowances for failures, which are very common with most observers, a rough estimate shows that he spent 286 hours with the shutter open taking the Milky Way pictures alone, and in the list many continuous runs of five hours, six hours, and even seven hours are found, and one of them (the picture that shows the nebulosities around the *Pleiades*) is of ten hours and fifteen minutes' exposure.

The results of these indefatigable labors are a wonderful addition to our knowledge of the Milky Way and of comets. The human eye directly, no matter how great the power of the telescope, could never have seen the structure of the Galaxy or of comets' tails. The cumulative effect of light on a photographic plate and the fact that it does not require a magnification of four or five to each inch of aperture, as does the human eye, makes these wonderful pictures possible.

There is one thing about these pictures, however, that it is well enuf to bear in mind. The relation between the brightness of the stars and the brilliance of the nebulosities is a purely artificial one. It would be possible to photograph every one of the stars upon these plates without showing a particle of nebulosity. It would also be possible to photograph the nebulosities and show scarcely any stars. A short-focus lens of great relative aperture "sees" the nebulosity rather than the stars and a long-focus lens of small aperture and great defining power would take the stars and not the nebulosity.

I must not say anything about the pictures in detail. They speak for themselves, and added to that, Professor BARNARD has for many of them pointed out features and made judgments which to the reviewer seem on the whole most just and conservative. Undoubtedly, however, there will be considerable difference of opinion as to how certain features should be explained. Some of the forms shown in the Milky Way must be due to chance, just as the "crouching beast" (Plate 45) is, and it would be folly to try to explain forms that have only accident for their cause. That remarkable line of stars on Plate 39 may be an example. If a person should splash ink in small spots on a wall, he would doubtless discover some interesting forms, but they would be as imaginary as the Castles or the Camels of the Clouds. There are other pictures, however, in which the streaming of stars in lines and net-work seems most real.

The interpretation of the vacancies and the lanes is interesting. Professor BARNARD thinks that in certain cases the absence of stars is due to an absorbing medium simply covering up the stars, and that the large telescopes to which he has had access show some of these to be slightly luminous. One could wish that he had correlated these observations with some of his more recent photographs of dark lanes, where, if the writer's memory serves, he took the point of view that the lanes were darker than the general background of the sky on his plates. It is possible that this difference might be reconciled,—perhaps by the difference in the instruments. Could an object be darker than the surrounding sky to a Petzval doublet and brighter to the human eye in a 40-inch refractor?

Professor BARNARD's comet pictures are most interesting. Brooks' Comet of 1893 must have been much like and perhaps more remarkable than the famous Morehouse Comet. It is a pity that other astronomers did not get a series of photographs of it, for it evidently would have given opportunity, even better than Morehouse's Comet, for measurements of regression of luminous matter in the tail.

Professor BARNARD's ingenious and successful combinations of photographs taken on different nights to show the freak motions and changes in the tail are also most interesting. That these changes cannot all be explained by eruptive disturbances and by varying speeds of repulsion of luminous particles from the head, without the necessity of assuming some kind of streaming in space, does not seem to me proved.

The volume as a whole is a notable contribution to astronomy. It is a great credit to the Lick Observatory, to the people whose generous contributions made its publication possible, to the Willard lens, and, most of all, to Professor BARNARD.

WINCHESTER, MASS., November 4, 1914.

NOTE ON A 570.

By ERIC DOOLITTLE.

The recent announcement by Dr. AITKEN, in *A. S. P.*, XXVI, page 205, in regard to the interesting and rapid binary A 570, was of special interest to me because for some years I have been keeping watch of this important pair. I find that I have secured measures of it on twelve nights altogether, and while in view of Dr. AITKEN's most accurate measures these must lose much of their value, yet as two of the series of measures were secured during years when the pair was not measured at the Lick Observatory, they may be of a certain supplementary interest. My measures in full are as follows:—

1909.460	148°.98	0″.2 ±	7.0	7.0	R	8–0	(*a*)
1909.463	157 .63	0 .25 ±	...	...	R	8–0	(*b*)
1909.465	149 .02	0 .24	6.5	6.5	P	4	(*c*)
1909.471	153 .18	0 .29	7.0	7.0	R	6	(*c*)
1913.263	103 .88	0 .24	7.0	7.0	P	8	(*c*)
1913.296	109 .40	0 .20 ±	...	...	P	6–0	(*d*)
1913.504	96 .75	0 .20 ±	7.0	7.0	R	6–0	(*e*)
1913.542	94 .81	0 .26	...	...	P	8	(*c*)
1914.458	84 .66	<0 .2	...	...	P	6–0	(*f*)
1914.479	86 .63	0 .2 ±	...	...	P	6–0	(*f*)
1914.542	79 .95	<0 .2	...	...	P	8–0	(*f*)
1914.570	91 .74	0 .2 ±	...	...	P	6–0	(*f*)
1909.46	152°.2	0″.24	6.8	6.8		4–2*n*	
1913.40	101 .2	0 .22	7.0	7.0		4	
1914.51	85 .6	<0 .2	...	...		4	

(*a*) A perfectly distinct elongation. (*b*) A very difficult star; much closer than β 1111. (*c*) Perfectly and widely separated. (*d*) Almost distinct, and, in fact, distinct at long intervals. (*e*) Much elongated; magnitudes equal. (*f*) Clearly elongated, but never separated completely. I think it certain that the star is much closer than last year.

During the last year Dr. AITKEN obtains for the distance of the pair, 0″.16.

UNIVERSITY OF PENNSYLVANIA, November, 1914.

(EIGHTY-SECOND) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Professor H. H. KRITZINGER, of Bothkamp, Germany, for the discovery of an unexpected comet on March 28, 1914.

Committee on the Comet-Medal:
W. W. CAMPBELL,
R. H. TUCKER,
H. D. CURTIS.

(EIGHTY-THIRD) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur V. Zlatinsky, of Mitau, Russia, for the discovery of an unexpected comet on May 15, 1914.

Committee on the Comet-Medal:
W. W. Campbell,
R. H. Tucker,
H. D. Curtis.

(EIGHTY-FOURTH) AWARD OF THE DONOHOE COMET-MEDAL.

The Comet-Medal of the Astronomical Society of the Pacific has been awarded to Monsieur G. Neujmin, of Simeis, Russia, for the discovery of an unexpected comet on June 24, 1914.

Committee on the Comet-Medal:
W. W. Campbell,
R. H. Tucker,
H. D. Curtis.

NOTES FROM PACIFIC COAST OBSERVATORIES.

REPORT OF THE DIRECTOR OF THE LICK OBSERVATORY.

To the President of the University.

SIR: I have the honor to submit herewith my report for the period July 1, 1913, to May 31, 1914.

It is a pleasure to be able to say that a good start has been made in removing the arrears of publication. Volume VII, *Publications of the Lick Observatory,* containing papers by members of the Berkeley Astronomical Department, whose printing began in the year 1902, has now been completed. It was distributed to our correspondents in May, 1914.

Volume XI, *Publications of the Lick Observatory,* containing reproductions and brief descriptions of Professor BARNARD's Milky Way and comet photographs, is now in the binding stage in the State Printing Office, and we hope to distribute it to our correspondents in July or August, 1914. The cost of the plates, printing and paper for the 129 full-page illustrations was borne by subscriptions received from friends of the observatory, by Profesor BARNARD's personal contributions, and, to a minor degree, by funds taken from the Lick Observatory maintenance budget. The printing of the text and the binding of the volumes have proceeded on the basis of a Regents' appropriation.

In April, 1914, the Regents made a liberal appropriation in support of Lick Observatory printing, to become available on July 1, 1914. It is hoped that the printing of Volume XII, *Publications of the Lick Observatory,* to contain Mr. AITKEN's observations and studies of the more interesting visual double stars which he made during the years 1896-1913, may begin in July and proceed without interruption. The contents of this [illegible] to the excellence of Mr [illegible] program of [illegible] in following that program will form [illegible] to our knowledge of double [illegible]

[illegible] of Halley's Comet [illegible] expedition [illegible] to the publication of the [illegible]

[illegible]

Extensive preparations have been made to observe the total solar eclipse of August 21, 1914, in continuation of observations secured at the favorable eclipses occurring since the opening of the Lick Observatory in 1888. Regent WILLIAM H. CROCKER has generously given the sum of $5,800 to defray the expense. Director CAMPBELL and Astronomer CURTIS will leave Mount Hamilton about June 10th, to establish the observing station in the vicinity of the city of Kiev, Russia. Twelve or more volunteer assistants, partly from this country and partly from Europe, will join the expedition to assist in the making of the photographs at the time of totality.

It has seemed to many astronomers that the time has come to determine the accurate positions of the fainter stars, say those fainter than the eighth visual magnitude, by means of photographs instead of by the prevailing meridian-circle visual method; reserving the visual method for extremely accurate observations of the brighter stars. The Allegheny Observatory is undertaking to apply the photographic method to a narrow zone of faint stars extending around the sky; and Professor TUCKER of our staff is securing the meridian-circle observations of six hundred of the brighter stars distributed uniformly thruout this zone, to form the skeleton, so to speak, upon which the positions of the fainter stars will depend. The four thousand individual observations required in our share of the program, and the computations related thereto, will consume the resources of our meridian-circle department during the current year. Twelve hundred and sixty of the observations have been secured by Mr. TUCKER since January 28th of this year.

In the prosecution of our double-star survey in the current academic year, Professor AITKEN has discovered 245 double stars, and has made accurate measures of 470 doubles. His discoveries to date number 2,845 pairs. Professor HUSSEY co-operated in the survey during the years 1899-1905, and discovered 1,328 pairs; making a total of 4,173 for the two observers. In essentially all of these pairs the two component stars are less than five seconds of arc apart. In the three-fifths of the sky thus far covered by the survey there are fewer than seven thousand such pairs as bright as the ninth magnitude.

Fully sixty per cent of all known double stars of this class in the region observed have been found in the progress of our survey. From Mount Hamilton the observations can be made to advantage as far south as declination —[illegible] for the winter sky and declination —[illegible] for the summer sky. In the area extending from the north pole of the sky to the southern limits just described, [illegible] stars, or approximately one per cent of the whole number as bright as the ninth magnitude, remain to be examined. The work will be brought to a close before the end of the present calendar year. The double-star survey, which was begun by [illegible] in April, [illegible], should be extended over the [illegible] hemisphere of the sky, by means of a similar instrumental equipment—a [illegible]—and [illegible]. Financial conditions have prevented me from [illegible] to this end.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Mr. WRIGHT has continued his observations of the spectrum of the new star in *Gemini,* making them doubtless by far the most extensive observations of the new star that have been secured. An important paper on the subject is essentially ready for publication. The observations of new stars in the past generation have inclined astronomers to the view that they represent the results of some celestial catastrophe, such as the collision or close approach of two stars, or the passage of a star thru some form of resisting medium. However, these very detailed and accurate observations of the spectrum of *Nova Geminorum* seem to add complexity to the general problem of novæ.

Professor CURTIS has continued the photographic survey of the more prominent nebulæ, with the Crossley reflector. The descriptions of 109 such nebulæ were published by him recently. Mr. CURTIS has also been rephotographing many of the brightest spiral nebulæ which were photographed by Professor KEELER in the years 1898-1900. His purpose has been the important one of determining whether these objects have moved appreciably across the sky in the past fifteen years, or whether they have rotated thru appreciable angles in this interval. These questions concern vitally the greater one of whether the spiral nebulæ are to be regarded as a part of our own stellar universe or whether, as some astronomers have believed, they are separate universes of stars so remote from our universe that we see them merely as unresolved small areas of light.

The work of the D. O. Mills Expedition in the southern hemisphere has been vigorously prosecuted by Dr. WILSON and his assistants. The program has embraced the securing of many two-prism spectrograms of the stars between 5 and 5½ visual magnitudes; of one-prism spectrograms of the brighter stars whose spectra lines are too hazy for accurate measurement on the basis of two-prism dispersion; and of one-prism spectrograms for determining the radial velocities of the planetary nebulæ. Essentially all of the plates have been measured in duplicate. About twenty-five spectroscopic double stars have been discovered since the date of my last report; the greater number during the closing months of Dr. MOORE'S administration, which continued to August 9, 1913, and the remainder during Dr. WILSON's administration.

Messrs. MOORE and SANFORD have published an extremely interesting investigation of the spectrum of *Eta Carinæ,* a southern star whose violent fluctuations in brightness have made it an object of close attention for more than two centuries. The value of this study lies principally in its close connection with the general problem of new stars, inasmuch as *Eta Carinæ* has many of the characteristics of novæ, and is thought to have appeared originally as a nova.

Mr. MOORE has published a thorough investigation of the variable and spectroscopic binary star *Delta Cephei.*

The principal spectrographic observations at Mount Hamilton in the period covered by this report have had for their purpose the determination of the radial velocities of the planetary and certan other nebulæ, in continuation of Professor KEELER's visual observations of fourteen nebulæ with the 36-inch refractor in the years 1890-91. KEELER's observations showed that the Great Nebula in *Orion* is substantially at rest in space, as far as motion to or from the position occupied by our solar system is concerned, and that the planetary nebulæ are travelling rapidly. Studies of stellar velocities, as observed with the Mills spectrographs at Mount Hamilton and in Chile, had led to the important discovery in 1910 that the average stellar velocities increase with advancing spectral types. It was natural that the results for the stars should be compared with those available for the nebulæ; and it was found that the average velocities of the planetary nebulæ are very much higher than those of the stars supposedly young, and appreciably higher than those of the stars presumed to be oldest. As a result of these facts, serious doubt fell upon the generally accepted theory, dating back to the days of Sir WILLIAM HERSCHEL, that the stars in general are formed from planetary nebulæ by processes of evolution. It became important to observe the radial velocities of as great a number of the nebulæ as possible. More than one hundred nebular spectrograms have been secured for this purpose with the 36-inch refractor and a one-prism spectrograph in the past year, and occasional observations of the planetary nebulæ have been made in Chile during the past three years. We now have quite accurate determinations of the radial velocities of forty nebulæ altogether. They confirm the earlier results that planetary nebulæ are travelling with speeds far beyond those of the stars in general. The average radial velocity of the forty observed planetary nebulæ is in excess of 40 kilometers per second, whereas the average velocities of the stars vary from 6 kilometers per second for those supposedly youngest up to 17 kilometers per second for those supposedly oldest. The effect upon our ideas of the connection existing between planetary nebulæ and the stars is revolutionary; apparently the stars in general have not been evolved from planetary nebulæ.

It is of interest to note that one planetary nebula observed at Mount Hamilton has a velocity of recession amounting to approximately 150 kilometers per second, and that another planetary nebula observed at Santiago has a velocity of approach equal to 136 kilometers per second. Several nebulæ have velocities to or from us in excess of 60 kilometers per second.

In many other respects also the observations of nebulæ have assumed high importance, and it is intended to devote many of our resources to the subject during the coming year.

A considerable number of stellar spectrograms has been obtained with one-prism and three-prism dispersion at Mount Hamilton, in the past year, to supplement various phases of our stellar radial velocity program, and many minor studies of the spectrograms have been conducted by Dr. MOORE, Dr. PADDOCK, and Miss HOBE.

Seven comets have been observed for accurate position. In nearly all cases these observations have been used by the Berkeley Astronomical Department in computing the orbits of the comets concerned.

The Martin Kellogg Fellowship has been filled during the present year by Dr. ELI STUART HAYNES. His principal investigation concerns the well-known variable star SZ *Tauri*. A noted student of variable stars proposed the hypothesis that this star is of ellipsoidal form, and in rotation about one of its shorter axes, with the effect that maximum light occurs when the stars presents itself broadside to us, and minimum brightness when the longer axis points toward us. If this be the true cause of the observed variations and the star be single, the radial velocity of the star would be constant. Mr. HAYNES obtained twenty-nine spectrograms of the star, and his measures of them establish that the radial velocity is variable. The maximum brightness occurs when the star has the maximum velocity of approach, and the minimum brightness when the star has its maximum velocity of recession. These characteristics assign the object to the well-known Cepheid type of variation.

Mr. HAYNES has observed asteroid No. 694 on five nights and *Jupiter's* sixth satellite on five nights.

Mr. HAYNES has been appointed Associate Professor of Astronomy in Beloit College.

Mr. AITKEN conducted the astronomical classes in the Summer Session of 1913 in the University.

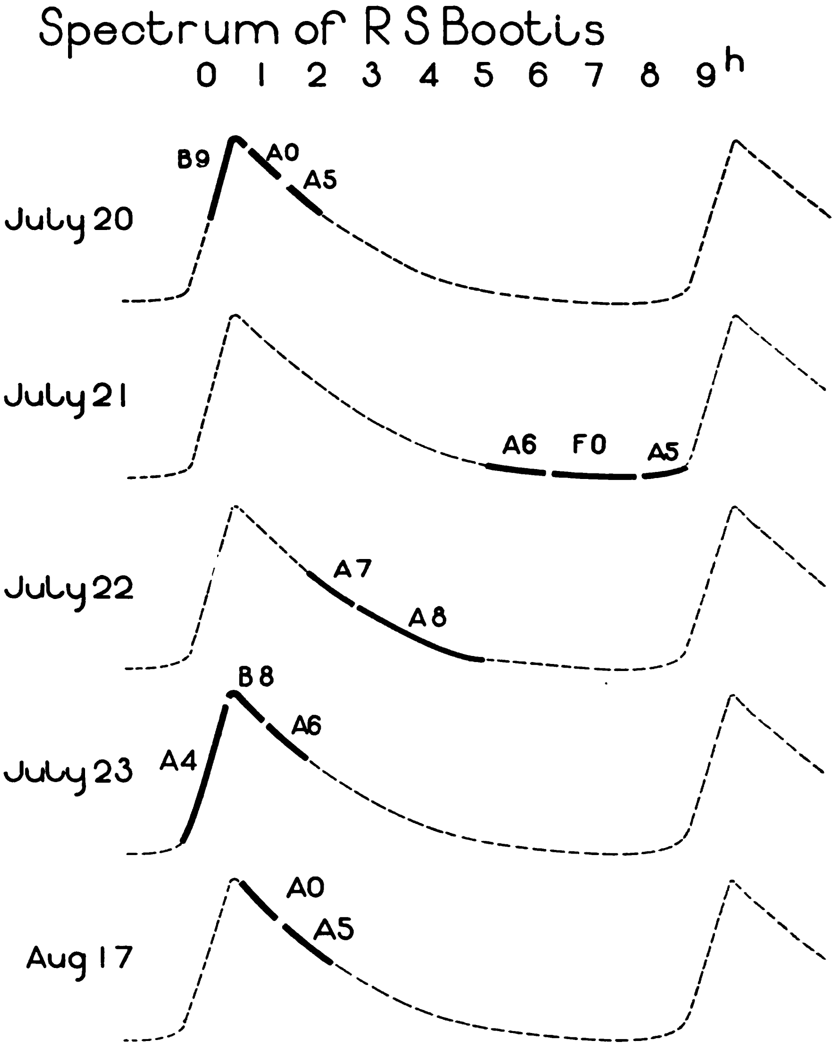
Mr. CAMPBELL represented the University at the meeting of the International Union for Co-operation in Solar Research at Bonn in July and August, 1913, and at the meeting of the Astronomische Gesellschaft at Hamburg in August, 1913.

The Director acknowledges the continued cordial support of the staff, both at Mount Hamilton and at Santiago, Chile.

Respectfully submitted,

W. W. CAMPBELL,
Director of the Lick Observatory.

MOUNT HAMILTON, June 1, 1914.


Spectrum of R S Bootis
0 1 2 3 4 5 6 7 8 9h
July 20
B9
A0
A5
July 21
A6
F0
A5
July 22
A7
A8
July 23
B8
A6
A4
Aug 17
A0
A5

SPECTRUM OF THE CLUSTER-TYPE VARIABLE RS BÖOTIS.

Thirteen good spectrum plates of the cluster-type variable RS *Böotis* were obtained with the small focal plane spectrograph attached to the 60-inch reflector on July 20-23, and on August 17, 1914. The plates were taken at maximum and minimum and at several points between to determine whether the spectrum varies.

The plates are as follows:

No.	Date	Exposure, P.S.T.		Actual Exposure Time in Minutes	Type
26	1914. July 20	$8^h\ 58^m$ —	$9^h\ 34^m$	35	B0
27		9 42	10 13	30	A0
28		10 22	10 58	35	A5
35	21	8 04	9 06	60	A6
36		9 16	10 47	90	F0
37		10 54	11 40	45	A5
40	22	8 04	8 52	45	A7
41		8 58	11 12	105	A8
43	23	8 59	9 45	40	A4
44		9 49	10 25	35	B8
45		10 33	11 12	40	A6
57	Aug. 17	7 37	8 17	40	A0
58		8 24	9 19	45	A5

The position of the plates is plotted along the light curve recently obtained by SEARES and SHAPLEY. Owing to difference in quality of the plates and to the small scale, the actual variation of type from the revised values given may be from one to two tenths of a Harvard unit. At maximum the hydrogen lines $H\beta$, $H\gamma$, $H\delta$ and $H\epsilon$ are strong and broad, the calcium line K being almost invisible; at minimum the intensities are reversed, the hydrogen lines being fine and narrow with H and K strong. Between these there is a gradual transition from one type to the other.

Mr. ADAMS has measured the plates to determine, if possible, whether the star is a spectroscopic binary. The scale is so small, however, ($H\gamma$ to $K = 2{\cdot}4^{mm}$), that the results are inconclusive beyond an indication that any variation in velocity must be moderate in amount.

F. G. PEASE.

MOUNT WILSON SOLAR OBSERVATORY.

THE SPECTRA OF TEN STARS OF VERY LOW LUMINOSITY.

The spectral classification of the following ten stars is of interest because they are among the very faintest stars intrinsically that are known:—

	Mag	R.A. 1910 h m	Dec. ° ′	μ ″	π ″	(*Sun* = 1) Lum.	(*Sun* = 5.5) Abs. Mag	Spec.
Comp. to *o Eridani* .	9.1	4 11.2	—7 48	4.08	+0.174	0.012	10.3	Ao
Lal. 21185	7.6	10 58.4	+36 35	4.77	0.403	0.009	10.6	Ma
Lal. 21258	8.9	11 1.1	+43 59	4.46	0.203	0.011	10.4	Ma
A Oe 17415-6	9.3	17 37.0	+68 26	1.31	0.268	0.004	11.4	Mb
Comp. to *μ Herculis*	11.0	17 42.9	+27 46	0.31	0.106	0.006	11.1	Ma
Pos. Med. 2164 ...	9.3	18 41.9	+59 30	2.28	0.292	0.003	11.6	Ma
Comp. to 17 *Lyræ*..	12.0	19 4.0	+32 21	1.66	0.15	0.001	12.9	Ma
Lal. 40844	9.0	21 0.9	+6 43	0.57	0.167	0.014	10.1	K6
Kruger 60	9.2	22 24.8	+57 15	0.92	0.256	0.005	11.2	Mb
Lal. 46650	8.9	23 44.5	+1 55	1.40	0.183	0.013	10.2	Ma

No less than eight of the ten stars are of type M, while one of the remaining two is of the advanced type K6. The A star, companion to *o Eridani*, has been referred to in a previous note in this publication. The great preponderance of the M type of spectrum is of especial importance in its bearing on the colors of faint stars.

It is of interest to note that in all of these stars, except the Ao star, the calcium lines at λ 4435 and λ 4455 are very prominent. We have found previously that these lines appear to serve as an excellent criterion of absolute magnitude.

W. S. ADAMS and F. G. PEASE.

COLOR INDICES IN THE SYSTEM OF TW ANDROMEDÆ.

For the purpose of determining simultaneously the photographic and photovisual light curves of the eclipsing binary TW *Andromedæ,* and in particular to ascertain the relative color of the faint companion, a series of observations has been undertaken with the 60-inch reflector. Sixty-five plates, representing a total of nearly 300 exposures, have been secured up to the present, and since considerable time must elapse before the observations can be completed and the plates measured and discussed, provisional results will be reported in the present note.

It was known from photometric observations made at Brussels and elsewhere that at deepest phase of the principal minimum of TW *Andromedæ* the light remained constant for two hours or more. From the total duration of the minimum and the range of variation it is easy to show that the principal eclipse must be total; that is, the bright star is then completely obscured by a relatively large and faint companion. Obviously, then, the photographic and photovisual magnitudes at that time give the color of the faint companion, and, neglecting possible effects of absorption in space, give also an indication of its spectrum.

Observations have been made at three epochs of principal minimum, and at two the constant minimum phase was observed. Exposures were made alternately on Seed 27 plates and on Cramer isochromatic plates used in connection with a yellow filter. The magnitudes of the companion stars were determined by means of diaphram plates and the zero points fixed by exposing alternately on stars of the North Polar Sequence and on the field of the variable. Judging from the color indices, the comparison stars are of spectral types A and F. The results given below must be considered provisional, but it is not likely that these values will be changed greatly with the completion of the study of the light curve.

The magnitudes for the variable are as follows:

	Photographic	Photovisual
Magnitude at maximum	9.74	9.09
Magnitude at minimum	11.78	10.72
Range	2.04	1.63
Light of brighter component	85%	78%
Magnitude of brighter component	9.92	9.36

The color index of the faint component is the difference between the photographic and photovisual magnitudes at minimum. The magnitude at maximum, however, represents the combined light of both components. To get the light of the brighter component alone, we subtract 15 per cent of the total from the photographic light at maximum and 22 per cent from the photovisual, with the results given above.

The color index of the bright star is + 0.56, corresponding to a spectrum of type F3, and that of its large faint companion,

+ 1.06, corresponding to G4. It will be possible to check the relation between color index and spectral type in this instance by a direct classification of both spectra.

A preliminary solution for some of the orbital elements of the system permits a rough determination of the density of the two stars. It is found that for the faint component the density in terms of the Sun will not exceed a few hundredths and may be much less; for the brighter component the density will probably not be less than four tenths that of the Sun, a value in good agreement with the known density of several F-type eclipsing stars.

The change in color at a total eclipse has been determined definitely heretofore in the case of only one star, namely for RR *Draconis*, by SEARES, using the 60-inch reflector. In that case a similar result was obtained; the photographic range was found to be $3^m.82$, while the photovisual range was $0^m.57$ less. In the system of RR *Draconis*, as in TW *Andromedæ*, the fainter, redder companion is probably much less dense than its bluer primary. It has in both systems many times the volume of the brighter component and probably has smaller mass. We may expect, then, that the atmospheric conditions are not the same and that, as a consequence, the difference in color indices between the two components may possibly be due in part to peculiar atmospheric absorption rather than to conspicuous difference in spectral type.

HARLOW SHAPLEY.

MOUNT WILSON SOLAR OBSERVATORY,
November 7, 1914.

THREE STARS WITH BRIGHT HYDROGEN LINES.

The following stars have one or more bright hydrogen lines in their spectra:—

Boss 1215	6.0	B6	5^h $2^m.5$	+21° 35′	Hβ and Hγ
BD — 8° 4352	8.8	Ma	16 50 .7	— 8 10	Hβ, Hγ, etc.
BD +13° 4692	6.6	B6	21 19 .5	+13 40	Hβ

The most interesting of these stars is the second. It has a proper motion of $1''.29$ annually, and a measured parallax of $0''.210$. Its absolute magnitude, therefore, (*Sun* = 5.5) is

10.4. This star furnishes a proof of the possibility of the existence of bright lines in the spectra of stars of very low intrinsic brightness.
W. S. ADAMS.

TEN SPECTROSCOPIC BINARIES.

The following stars have been found to be spectroscopic binaries:—

	Mag.	Spec.	R.A. 1910	Dec.	Range in Velocity km		
Boss 9	6.3	G5	0^h $3^m.8$	— 2° 55′	—15	to	+16
Boss 1177	5.6	A0	4 52 .6	+24 55	+ 1		+49
Boss 2381	5.5	A2	8 47 .2	— 6 50	+10		+56
Boss 2484	5.8	A2	9 11 .5	+47 12	—14		+76
Lal. 18397	7.7	G7p	9 16 .8	+40 38	—16		—54
Boss 3323	5.0	A5p	12 41 .2	+ 8 9	—43		+36
Boss 3428	7.1	B9p	13 8 .6	—18 21	—100		+17
Boss 3540	6.3	A0p	13 39 .2	— 5 3	—63		+41
Boss 4660	5.7	F7	18 21 .6	+ 7 59	—46		— 4
Boss 5070	5.7	B3	19 47 .5	+40 22	—54		+86

The spectrum of Lal. 18397 is composite.
W. S. ADAMS.

PHOTOGRAPHIC ALBUM OF THE ECLIPTIC ZONE.

Under the auspices of the Astronomical Society of Spain and America, J. COMAS SOLÁ, Director of the Fabra Observatory, Barcelona, Spain, has undertaken to photograph the entire ecliptic region with a Petzval objective, 16^{cm} in diameter and 80^{cm} focal length. Forty photographic plates, 18 × 20^{cm}, covering an effective field of 10° × 12°, will take all the stars of the ecliptic zone down to the thirteenth magnitude. The reseau put on each plate will make the determination of coördinates easy and accurate. The stars are allowed to trail for a short time to show the east-west direction. Two exposures are given to each plate to make the difference between defects and photographic images clear. The separation of the two images is $30'' = 1/8$ of a millimeter on the photographic plate. Small planets may be dscovered or rediscovered in this way, since neither the separation of the images nor the direction of the trails will be the same as for the stars. The negatives will be reproduced on heavy glossy paper and the album will be made up of forty plates. In the album those objects only will be marked that show special features, on account of the magnitude, spectral type, parallax, binary system, proper motion, radial velocity or variability of the star, or because they are asteroids or nebulæ. J. COMAS SOLÁ expects to finish his work by the middle of 1915. The album of plates can be secured from the secretary of the society, Mr. F. ARMENTER, Plaza Real 13, Barcelona, Spain, at the price of ten dollars.

M. SELGA, S. J.

MINUTES OF THE SPECIAL MEETING OF THE BOARD OF DIRECTORS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, HELD IN THE ROOMS OF THE SOCIETY, 752 PHELAN BUILDING, SAN FRANCISCO, ON NOVEMBER 28, 1914, AT 2:00 P. M.

There were present President R. T. CRAWFORD and Directors AITKEN, CUSHING, COSTA and RICHARDSON. Director RICHARDSON held the proxies of Directors BURCKHALTER, TOWNLEY and MARKWART.

Action was taken upon the award of the Bruce Gold Medal for the year 1915, report of which will be made later.

On motion of Director AITKEN, the following were elected members of the Society:—

Prof. M. SELGA, S. J., of the Observatory of Manila, P. I.
Dr. E. S. HAYNES, of Smith Observatory, Beloit, Wis.

Director CUSHING made a verbal report upon the situation resulting from the failure of the People's Water Company to pay the accrued interest upon the underlying bonds of the Contra Costa Water Company, of which the Society holds three. It was the sense of the Board that no action looking to a compromise of the rights of the Society in the premises should be taken at this time.

The following committees were appointed by the President to report at the annual meeting in January, 1915:—

Auditing Committee—C. S. CUSHING (Chairman), F. V. CORNISH, A. B. BAIRD.

Nominating Committee—B. L. HODGHEAD (Chairman), Dr. S. EINARSSON, J. D. GALLOWAY.

President CRAWFORD invited the attention of the Board to the fact that the important work of the International Latitude Observatories was threatened, and liable to be discontinued, as a result of the war conditions in Europe. Upon his suggestion the following resolution was prepared and unanimously passed by the Board:—

WHEREAS, It has come to the attention of this Board that the work of the International Latitude Observatories is threatened by the present war in Europe, and that some of the stations may be closed; be it

Resolved, That it is the sense of the Astronomical Society of the Pacific that the work of these stations is of the greatest importance, and that every effort should be made to continue the stations in this country even though others are necessarily closed;

Resolved, That the President and Secretary of this Society be authorized and instructed to present the views of this Society to the proper authorities of the United States Government and urge upon them the desirability of making some special provision for the maintenance of the stations in this country.

Adjourned.

MINUTES OF THE MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, AT THE STUDENTS' OBSERVATORY, BERKELEY, ON NOVEMBER 30, 1914, AT 8:00 P. M.

The meeting was called to order by President **CRAWFORD**.

On motion of Dr. A .O. **LEUSCHNER**, seconded by F. R. **ZIEL**, a resolution was passed, endorsing the action of the Board of Directors at the meeting of November 28th, asking the proper authorities of the United States Government to make provision for continuing the work of the International Latitude Observatories in this country.

Mr. **CHARLES BURCKHALTER**, Director of Chabot Observatory, made a few remarks relative to the progress being made on the work of the new telescope for his observatory. He said that word had been received of the successful casting of the discs for the lenses at Jena, and that this removed the principal difficulty to be overcome in building the instrument. He reported also the selection of a most desirable site for the new observatory at Leona Heights, East Oakland, and expressed the hope that within a year he would have a comfortably equipped establishment which would be a credit to the School Department of Oakland and in a position to do much for the advance of astronomical knowledge.

The address of the evening was delivered by Dr. **HEBER D. CURTIS**, of Lick Observatory, whose subject was: "An Eclipse Camp in War Time: The Lick Observatory-Crocker Expedition to Observe the Total Solar Eclipse of August 21, 1914, in Brovary, Russia."

As was anticipated, this subject proved to be a most attractive one to the public and drew an appreciative audience, which filled the lecture-room of the Students' Observatory, notwithstanding the fact that the first storm of the season was howling outside.

The experiences of the eclipse party in Russia, just as the war was breaking out, were most entertainingly recited and illustrated, and proved, among other things, that Dr. **CURTIS** is not only an astronomer, but a wit, a poet, a diplomat and many other things which go to make up the ideal man for an eclipse expedition.

A vote of thanks was returned to Dr. **CURTIS** and then everybody went out into the rain.

OFFICERS OF THE SOCIETY

Mr. R. T. Crawford	*President*
Mr. R. G. Aitken	*First Vice-President*
Mr. S. D. Townley	*Second Vice-President*
Mr. C. S. Cushing	*Third Vice-President*
Mr. D. S. Richardson	*Secretary-Treasurer*
Mr. R. G. Aitken	*Secretary on Mount Hamilton*

Board of Directors—Messrs. A. B. Baird, R. G. Aitken, W. H. Crocker, Charles Burckhalter, C. S. Cushing, R. T. Crawford, J. Costa, S. D. Townley, F. V. Cornish, A. H. Markwart, D. S. Richardson.

Finance Committee—Messrs. C. S. Cushing, W. H. Crocker, A. H. Markwart.

Publication Committee—Messrs. R. G. Aitken, H. D. Curtis.

Library Committee —Messrs. D. S. Richardson, F. V. Cornish, and A. H. Markwart.

Comet-Medal Committee—Messrs. W. W. Campbell, R. H. Tucker, and H. D. Curtis.

NOTICE

Article VIII of the By-Laws of the Society, as amended in 1903, reads as follows: "Each active member shall pay, as annual dues, the sum of five dollars, due on the first day of January each year in advance. When a new member is elected during the first quarter of any year, he shall pay full dues for such year; when elected during the second quarter, he shall pay three fourths only of such dues; when elected during the third quarter, he shall pay one half only of such dues; when elected during the last quarter, he shall pay one fourth only of such dues; provided, however, that one half only of the dues in this article provided for shall be collected from any member who is actually enrolled as a student at a university, seminary, high school, or other similar institution of learning, during such time as he is so enrolled. . . . Any member may be released from annual dues by the payment of fifty dollars at any one time, and placed on the roll of life members by the vote of the Board of Directors. . . ."

Volumes for past years will be supplied to members, so far as the stock on hand is sufficient, on the payment of two dollars per volume to either of the Secretaries. Single copies will be supplied on the following basis: one dollar to non-members, seventy-five cents to dealers, and fifty cents to members.

Members within the United States may obtain books from the library of the Society by sending to the Secretary ten cents postage for each book desired.

The order in which papers are printed in the *Publications* is decided simply by convenience. In general, those papers are printed first which are earliest accepted for publication. Papers intended to be printed in a given number of the *Publications* should be in the hands of the Committee not later than the 20th of the month preceding the month of publication. The responsibility for the views expressed in the papers printed, and for the form of their expression, rests with the writers, and is not assumed by the Society. Articles for the *Publications* should be sent to the chairman of the Committee on Publication, R. G. Aitken, Lick Observatory, Mt. Hamilton, California.

Reprints of the longer articles appearing in the *Publications* will be furnished free of cost, without covers, to the number of fifty copies, provided the request for such reprints is made at the time the manuscript is submitted. Binding in paper covers, or copies in excess of fifty, will be furnished at cost price.

Regular meetings of the Society are held in San Francisco or vicinity on the last Saturdays of January, March, June, and November, and at the Lick Observatory on the last Saturday of August. Members who propose to attend a meeting at Mount Hamilton should communicate with the Secretary-Treasurer, in order that arrangements may be made for transportation.

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